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**USATHAMA**

U.S. Army Toxic and Hazardous Materials Agency

**PILOT-SCALE TESTING  
OF PAINT WASTE INCINERATION**

(TASK ORDER NO. 1)

July 1989  
Contract No. DAAA15-88-D-0001

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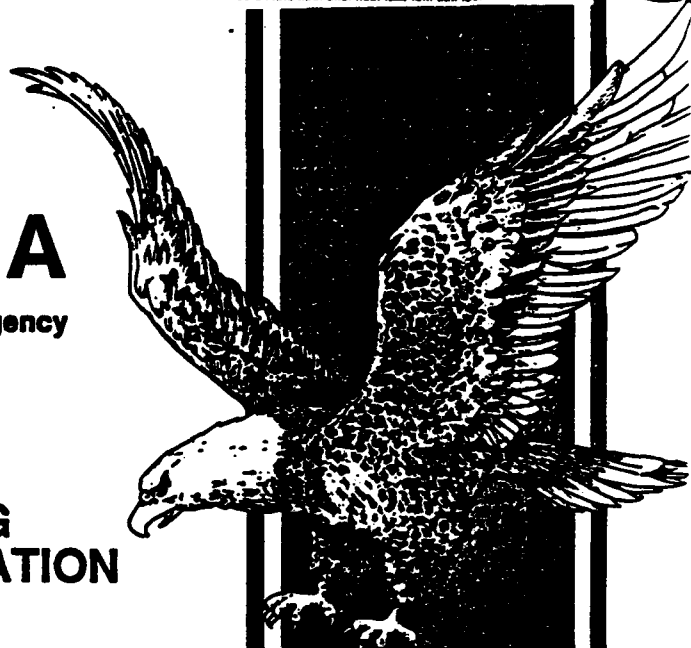
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## ABSTRACT PAGE TWO

Pilot-scale incineration tests were conducted in August 1988 at the John Zink Co. incineration test facility in Tulsa, Oklahoma. The primary combustion chamber used in these tests was a rotary-kiln incinerator. The kiln operating temperatures used were 1500° and 1800°F; the secondary combustion chamber temperatures were 1600° and 2000°F. Two residence times, 30 and 60 minutes, were evaluated at both kiln operating temperatures, which yielded a total of four tests. Each test consisted of two 2-hour sampling runs.

Sampling activities were conducted to allow characterization of the feed, ash, and air emissions. Samples of the paint waste feed were collected during each run and analyzed for selected metals and organic compounds. Proximate and ultimate analyses were also conducted on the paint waste. Samples of the kiln ash were analyzed for metals and organic compounds. The ash was also subjected to the EPA's Toxicity Characteristic Leaching Procedure (TCLP) extraction, and the extract was analyzed for metals and organic compounds.

Air emission samples were analyzed for volatile and semivolatile organics; metals; uncontrolled particulate loading rates and size distribution; and hydrogen chloride (HCl), nitrogen oxides (NO<sub>x</sub>), and sulfur dioxide (SO<sub>2</sub>) emissions. Continuous emissions monitoring (CEM) of carbon monoxide (CO), carbon dioxide (CO<sub>2</sub>), oxygen (O<sub>2</sub>), and temperature was also conducted.

Plastic and agricultural (walnut shells) blast residues were found to be readily incinerated by a conventional rotary-kiln system. The DRE's achieved for organic spiking compounds were greater than the performance standard of 99.99 percent under all operating conditions. During testing, 21 drums of blast residue were incinerated, and less than one-third drum of ash was generated (representing a waste volume reduction of over 98 percent). The kiln ash produced during six of eight tests did not exceed TCLP limits, and one test did not produce enough ash to characterize. Engineering data on the characteristics of air emissions, which were collected prior to the control device, will be used in a future project to evaluate the applicability of various gas cleaning systems.

Further study of paint waste incineration is needed before a full-scale unit can be designed. The following areas warrant further investigation: 1) evaluation of material handling aspects; 2) additional pilot tests of other paint wastes, characterization of wastes, ash generated, and emissions; 3) determination of applicable emission-control devices and assessment of residues generated; 4) cost evaluations and comparison of the cost-effectiveness of incineration with current practices; and 5) implementation of incineration at specific Army depots, as warranted.

FINAL REPORT  
PILOT-SCALE TESTING OF PAINT  
WASTE INCINERATION



by

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U.S. ARMY TOXIC AND HAZARDOUS MATERIALS AGENCY  
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## EXECUTIVE SUMMARY

PEI Associates, Inc. (PEI), prepared this report for the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) in response to Task Order No. 0001 under Contract No. DAAA15-88-D-0001. The John Zink Co. incineration test facility in Tulsa, Oklahoma, assisted PEI in the performance of the work.

## INTRODUCTION

Operations at the U.S. Army depots generate large quantities of paint removal and application wastes. These wastes, many of which are hazardous, are currently disposed of off site. Off-site disposal of solids is often by landfilling, which will be banned or highly restricted in the future. Several research activities have been initiated by USATHAMA to evaluate alternative technologies for management of paint wastes. The project described in this report involved pilot-scale incineration testing of two paint wastes: spent plastic blast media and spent agricultural blast media (ground walnut shells).

## OBJECTIVE

The objective of this task was to continue development of incineration as an alternative treatment technology for paint wastes through pilot-scale rotary-kiln incineration testing. The results of the pilot test were evaluated to assess how the paint waste characteristics and incinerator operating conditions affected the following:

- Characteristics of ash residue
- Volume reduction achieved
- Destruction and removal efficiencies (DRE's) for organic compounds
- Characteristics of stack gases

## EXPERIMENTAL PROCEDURES

Characteristics of paint wastes generated at the Letterkenny Army Depot (LEAD) in Chambersburg, Pennsylvania, were determined through review of previous USATHAMA studies and site visits. Based on the available data, especially the quantities of wastes generated, two wastes (spent plastic and walnut shell media) were selected for this test program. These two wastes were selected from a group of four generic paint wastes (spent blast media, chemical stripping wastes, application wastes, and spray-booth wastes), which included more than 14 individual waste streams.

Pilot-scale incineration tests were conducted in August 1968 at the John Zink Co. incineration test facility in Tulsa, Oklahoma. The primary combustion chamber used in these tests was a rotary-kiln incinerator. The system operating variables investigated were the temperatures in the kiln and the secondary combustion chamber and the residence time of waste in the kiln. The kiln operating temperatures used were 1500° and 1800°F; the secondary combustion chamber temperatures were 1600° and 2000°F. Two residence times, 30 and 60 minutes, were evaluated at both kiln operating temperatures, which yielded a total of four tests. Each test consisted of two 2-hour sampling runs.

Paint waste was fed to the kiln at a rate of approximately 195 lb/h during the tests. This waste consisted of equal amounts (by weight) of spent plastic and agricultural blast media (walnut shells). Water was added to this mixture to prevent excessive dusting during mixing and to prevent the dry, fine-grained blast media from being blown through the kiln by the combustion air. The waste was spiked with two organic compounds (chlorobenzene and 1,2-dichlorobenzene) to allow calculation of the destruction and removal efficiencies (DRE's) of both volatile and semivolatile organics.

Several sampling activities were conducted to allow characterization of the feed, ash, and air emissions. Samples of the paint waste feed were collected during each run and analyzed for selected metals and organic compounds. Proximate and ultimate analyses were also conducted on the paint waste. Samples of the kiln ash were analyzed for metals and organic compounds. The ash was also subjected to the EPA's Toxicity Characteristic Leaching Procedure (TCLP) extraction, and the extract was analyzed for metals and organic compounds.

Air emission samples were analyzed for volatile and semivolatile organics; metals; uncontrolled particulate loading rates and size distribution; and hydrogen chloride (HCl), nitrogen oxides ( $\text{NO}_x$ ), and sulfur dioxide ( $\text{SO}_2$ ) emissions. Continuous emissions monitoring (CEM) of carbon monoxide (CO), carbon dioxide ( $\text{CO}_2$ ), oxygen ( $\text{O}_2$ ), and temperature was also conducted.

## RESULTS

The incinerator feed material, consisting of a 1:1 mixture (by weight) of spent plastic media and spent walnut shells, was characterized prior to incineration. The average heating value of the blast media was 7700 Btu/lb (dry). The ash content ranged from 6.5 to 14.3 percent and averaged 11 percent. The elements of concern with regard to air pollution--sulfur, nitrogen, and chlorine--averaged 0.11, 12.4, and 0.09 percent, respectively. Concentrations of the primary metals of environmental concern--lead and chromium--averaged 5070 and 1470 ppm, respectively, in the blast media. Barium was also present in significant amounts; the average concentration was 500 ppm. Many of the metals in the untreated blast media varied in concentration between samples. For example, lead ranged from 1800 to 8320 ppm, and chromium from 600 to 2340 ppm. This variability is a reflection of the metal content of a particular sample of spent blast media being affected by many factors, including the metal content of the pigments in the paint removed, how readily the paint was removed (paints that are difficult to remove require more blast media and thus result in lower metal concentrations), and the efficiency of the blasting operation on different kinds of parts. No significant organic compounds were found in the feed samples.

Only one of the eight incineration tests conducted produced an ash that exceeded the TCLP criteria. This ash was generated during a test when the kiln temperature was 1800°F and the residence time was 60 minutes. The cadmium concentration in the extract was 7.1 ppm (TCLP limit = 1 ppm), and the chromium concentration was 32 ppm (TCLP limit = 5 ppm). Concentrations of lead and silver approached the TCLP limits of 5 ppm each. Although this test yielded higher concentrations of metals in the TCLP extracts than did the other tests, the total metals content in the ash was not generally greater. This apparent anomaly may indicate that the metals in the ash were



in a more leachable form than under the other test conditions. A second test under the same operating conditions did not produce enough ash to characterize. Of the metals quantified, lead, barium, and chromium were found in highest concentrations in the kiln ash. Lead concentrations ranged from 160 to 2900 ppm; barium, from 480 to 2100 ppm; and chromium, from 130 to 980 ppm (concentrations are average values of the results from two incinerator tests conducted under the same conditions). Arsenic, barium, and silver concentrations in the kiln ash increased over those in the feed material, whereas concentrations of the other metals decreased in the kiln ash.

The concentrations of organic compounds were generally below analytical detection limits in the incinerator ash and TCLP extracts of the ash generated during each test. Organics in TCLP extracts of the incinerator ash were below the prescribed land disposal treatment standards.

Sampling of the gas emissions indicated that more than 99.999 percent of the organic spiking compounds were destroyed under each test condition; this means the DRE performance standard of 99.99 percent for hazardous waste incinerators was surpassed for both the volatile (chlorobenzene) and semi-volatile (1,2-dichlorobenzene) principal organic hazardous constituents (POHC's).

Particulate loading to the control system was a function of both temperature and kiln residence time. Higher emission rates occurred at lower temperatures and longer residence times. Values of uncontrolled particulate loading ranged from 1.3 pounds of particulate emissions per 100 pounds of feed material at the 1800°F kiln temperature and 30-minute residence time to 6.5 pounds of particulate emissions per 100 pounds of feed material at the 1500°F kiln temperature and 60-minute residence time. These correlations between operating temperatures and residence times are consistent with general incinerator operating principles. Higher kiln and afterburner temperatures resulted in particulate emissions with smaller particle sizes, as would be expected. Residence time did not have a significant effect on particle size distribution.

The average  $O_2$  concentrations under all test conditions ranged from 5.4 to 8.4 percent, and average  $CO_2$  concentrations ranged from 9.2 to 11.4 percent. The set of  $O_2$  and  $CO_2$  data correlate with each other; i.e., higher  $O_2$  values correspond with lower  $CO_2$  values, as expected. The many CO spikes

that were observed during the first test can be attributed to difficulties keeping the incinerator at steady-state operating conditions during the first day; the average CO concentrations for these two runs was 308 ppm. Average CO concentrations during the remaining tests ranged from 14 to 24 ppm.

Average SO<sub>2</sub> concentrations in the emissions ranged from 10 to 24 ppm. Average NO<sub>x</sub> concentrations ranged from 72 to 154 ppm; higher process temperatures created more NO<sub>x</sub>, as expected.

Lead and zinc were the metals present in stack emissions in the largest amounts; lead emission rates ranged from 0.026 to 0.34 lb/100 lb dry feed, and zinc emission rates ranged from 0.015 to 0.18 lb/100 lb dry feed. Barium, cadmium, and chromium were also present in significant concentrations in the flue gas. (The data represent filterable plus condensable metal fractions.)

## CONCLUSIONS

Plastic and agricultural (walnut shells) blast residues were readily incinerated by a conventional rotary-kiln system. The DRE's achieved for organic spiking compounds were greater than the performance standard of 99.99 percent under all operating conditions. During the course of testing, 21 drums of blast residue were incinerated, and less than one-third drum of ash was generated (representing a waste volume reduction of over 98 percent). The kiln ash produced during six of eight tests did not exceed TCLP limits, and one test did not produce enough ash to characterize. Engineering data on the characteristics of air emissions, which were collected prior to the control device, will be used in a future project to evaluate the applicability of various gas cleaning systems.

## RECOMMENDATIONS

Further study of paint waste incineration is needed before a full-scale unit can be designed. The following areas warrant further investigation:

- ° Evaluation of material handling aspects.
- ° Additional pilot tests of other paint wastes; characterization of wastes, ash generated, and emissions.

- ° Determination of applicable emission-control devices and assessment of residues generated.
- ° Cost evaluations and comparison of the cost-effectiveness of incineration with current practices.
- ° Implementation of incineration at specific Army depots as warranted.

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## SECTION 1

### INTRODUCTION

#### 1.1 BACKGROUND

Army vehicles and equipment are repaired and refurbished at U.S. Army depots. These activities involve paint application and removal operations, which generate a variety of wastes. Paint removal operations such as chemical stripping and mechanical blasting generate large amounts of waste, and paint application operations generate both waste paint and solvents. Because these paint wastes contain potentially toxic organic compounds, corrosive liquids, or heavy metals, they have been classified as hazardous wastes.

Such wastes are currently disposed of offsite under commercial contract. Many of the solid paint wastes are disposed of by landfilling at RCRA-permitted facilities. Disposal is expected to present an increasingly difficult problem because of restrictions on land disposal of all hazardous wastes and the high costs and liability associated with this practice. Therefore, the development of alternative technologies to land disposal is needed to assist Army depots in the management of the hazardous waste they generate.

Two previous studies conducted by the U.S. Army Toxic and Hazardous Materials Agency (USATHAMA) have concluded that incineration of the paint wastes has the greatest waste-management potential, from both technical and cost-effectiveness standpoints.<sup>1,2</sup> The more recent of these studies, which involved bench-scale incineration testing of paint wastes, concluded that the resulting ash residue would not be hazardous according to the U.S. Environmental Protection Agency (EPA) Toxicity Characteristic Leaching Procedure (TCLP) criteria.<sup>2</sup> This study, however, did not address the organic fraction of the waste. Major conclusions from this study were as follows:

- 1) Incineration of all paint waste samples at temperatures of 700° to 1000°C (1300° to 1800°F) generated ashes that were not RCRA toxic by the TCLP test.



- 2) Temperatures of 1100°C (2000°F) and above decomposed chromium and barium compounds, which resulted in higher concentrations in the TCLP extract.

The study recommended pilot-scale testing of incineration to determine if subsequent treatment of the ash residue is needed and to determine the DRE's of organic compounds.

## 1.2 OBJECTIVE AND SCOPE

The objective of this task was to continue the development of incineration as a technology for paint waste treatment by pilot-scale testing of rotary-kiln incineration of these wastes. Specifically, the results of the pilot-scale test were evaluated to assess how the characteristics of the paint waste and operating conditions affected the following:

- ° Characteristics of the ash residue
- ° Volume reduction achieved
- ° Destruction and removal efficiencies (DRE's) for organic compounds
- ° Characteristics of the stack gases

## 1.3 TECHNICAL APPROACH

The general technical approach to this project consisted of performing seven discrete tasks, which are described briefly in the following paragraphs. Additional details regarding these tasks are presented in subsequent sections.

Task 1 involved the development of a detailed Program and Resource Plan addressing the technical approach to meeting the objectives of this project.

Task 2 involved the preparation of a Test Plan describing the procedures under which the incinerator tests would be performed to evaluate incineration as an effective treatment technology for paint wastes.<sup>3</sup> The Test Plan included sections on waste characterization, the incinerator test facility, operating conditions, operational data collection, feed and ash sampling, atmospheric emissions testing, analysis of samples, data analysis, and test residue disposal.

Task 3 involved determination of the characteristics of the paint waste prior to the incineration tests to facilitate 1) selection of wastes for

testing, 2) determination of handling and operating conditions, 3) development of an onsite sampling and analysis plan, and 4) completion of the appropriate Federal and State shipping manifests and disposal applications.

Task 4 entailed the preparation of an Accident Prevention Safety Program Plan to ensure the safety of all PEI, John Zink Co., and USATHAMA personnel involved in this project.<sup>4</sup> This plan was approved by the PEI and USATHAMA Safety Officers before the incineration tests were begun.

Task 5 involved the actual conductance of the pilot-scale testing. The paint wastes selected for incineration testing [agricultural blast media (ABM) and plastic blast media (PBM)] were shipped from Letterkenny Army Depot (LEAD) in Chambersburg, Pennsylvania, to the John Zink Co. facility in Tulsa, Oklahoma, in August 1988. The pilot-scale tests were completed over a 1-week period. Four tests were conducted with two residence times (0.5 and 1.0 h) and two rotary-kiln temperatures (1500° and 1800°F). Each test consisted of two 2-h runs. The paint waste feed, incinerator ash, and emissions from the rotary-kiln incinerator were sampled, and the incinerator operating parameters were monitored.

Task 6 involved an evaluation of the pilot-test performance to assess how the characteristics of the paint waste and the operating conditions of the incinerator affected the amount and characteristics of ash generated, the DRE's for organic spiking compounds, and the characteristics of the stack gases.

Task 7 entailed the preparation of project reports and documentation detailing the methods and results of the pilot study of this paint waste treatment technology. This document comprises the draft report for this project.

#### 1.4 REPORT ORGANIZATION

The remaining sections of this report present discussions regarding waste characterizations (Section 2), the incineration test facility (Section 3), and the test program (Section 4). The test data are presented in Section 5, and an evaluation of the data is given in Section 6. Conclusions and recommendations are presented in Section 7.

## SECTION 2

### WASTE CHARACTERIZATION

#### 2.1 PAINT-REMOVAL PRACTICES AT LEAD

Army depots generate paint wastes during both the application and the removal of paint from Army vehicles and equipment. The composition of the paint waste varies greatly with the type of paint involved and the method of application or removal. LEAD uses several types of paint, including primers, epoxies, polyamides, and polyurethanes [i.e., Chemical Agent Resistant Coating (CARC)]. Several colors of each paint are used, and each color is characterized by a different set of inorganic metallic pigments. Also, paints are reformulated over time, and the composition of the older paints being removed (e.g., nonpolyurethane paints containing chromium and lead) differs from that of paints currently being applied (e.g., polyurethane, chromium-free, and lead-free paints).

Application wastes include unused paints, residues generated during the cleaning of paint application tools with solvents, and wastes generated during the operation of spray booths. Paint-removal wastes result from the use of chemical strippers and mechanical blasting.

The following four general types of paint wastes are generated at LEAD:

- 1) Spent blast media (agricultural, plastic, metal, and glass)
- 2) Paint application waste (waste paint and solvents)
- 3) Spent spray-booth filters with trapped paint, floor sweepings, and Nanapeel<sup>tm</sup> (a rubberized spray-booth coating)
- 4) Spent chemical strippers and retained paint sludge

These wastes and their approximate rates of generation are summarized in Table 2-1.

TABLE 2-1. ESTIMATED PAINT WASTE GENERATION AT LETTERKENNY ARMY DEPOT<sup>2</sup>

Waste type	Quantity generated, 55-gal drums/yr	Distribution, gal/month	
		Paint	Other
Spent blast media	1000 to 1300	170	4400 (blast media)
Waste paint/solvents	600	45	2700 (solvents)
Spent spray-booth filters	360 to 480	300	NA <sup>a</sup> (filters)
Spent chemical strippers/ paint sludge	100	NA	460 (mixture)

<sup>a</sup> NA = Not available.

### 2.1.1 Spent Blast Media

Four media are used for removing paint from Army equipment and vehicles by blasting: 1) agricultural (ground walnut shells), 2) metal, 3) plastic, and 4) glass beads. The different media are collected separately from fabric filter hoppers in open-top, 55-gallon, steel drums (DOT17E). The volume of this waste is reduced by recycling larger media particles back into the blasting process. The spent blast media, a dry fine-grained waste, is currently landfilled offsite at a commercial treatment, storage, and disposal facility (TSDF). The spent blast media contain the medium itself and the dried paint removed during blasting. The dried paint consists of inorganic metallic pigments and organic constituents, but no volatile solvents.

The blast media account for about 50 percent by volume of the wastes generated at LEAD. The ABM is generated in the largest volume of the different media. Less residue is generated by the PBM because particle attrition is less and a greater fraction of particles can thus be recycled. For this and other reasons, USATHAMA and LEAD expect the use of PBM to increase in the future.

## 2.2 SELECTION OF WASTES FOR TESTING

As discussed in Subsection 2.1, numerous types of paint waste are generated at LEAD and characteristics within the same waste type vary greatly. The number of wastes tested was reduced so meaningful data could be obtained. Plastic and agricultural blast media were chosen for the first pilot-scale test because they account for approximately 50 percent of the paint waste generated at LEAD; ABM is the waste currently generated in the largest volume, and PBM is expected to be generated in larger quantities in the future.

### 2.3 CHEMICAL CHARACTERIZATION

Because characteristics of the paint wastes affected decisions regarding the incinerator operation, sampling, and analysis, these characteristics were determined before testing began. Waste characterization data were also needed for the accurate completion of the Hazardous Waste Shipping Manifest for transportation to the John Zink Co., the State of Oklahoma Disposal Plan Application, and the John Zink Waste Analysis Plan (required by the State of Oklahoma).

The characteristics of the paint wastes were determined by analyses of familiarization samples of ABM and PBM waste obtained from LEAD. Results of these analyses are presented in Tables 2-2 and 2-3. The metals of greatest environmental concern are lead, chromium, cadmium, and barium. These results are based on a composite of samples taken from several drums. During the incineration testing, more extensive sampling was conducted; resulting data are presented later in Section 5.

TABLE 2-2. ANALYSIS OF METALS IN FAMILIARIZATION SAMPLES (ppm)

Metals	ABM	PBM
Antimony	16.2	15.5
Arsenic	0.21	1.29
Barium	169	370
Cadmium	24.1	118
Chromium	321	15.5
Lead	1200	2195
Mercury	<0.14 <sup>a</sup>	<0.14
Selenium	<0.2	<0.2
Silver	<0.4	1.75

<sup>a</sup> < indicates the concentration of the metal was below the specified detection limit.

TABLE 2-3. INCINERATION PARAMETERS FOR BLAST MEDIA

Parameter	ABM	PBM
Heating value, Btu/lb	5580	6830
Sulfur content, %	0.51	0.07
Ash content, wt. %	6.90	8.67

## SECTION 3

### INCINERATION TEST FACILITY

#### 3.1 ROTARY-KILN INCINERATION SYSTEM

Pilot-scale incineration tests were conducted at the John Zink Co. incineration test facility in Tulsa, Oklahoma. This facility has several pilot-scale modular components that can be assembled in various configurations. Figure 3-1 presents a block diagram of the incinerator system that was used for these tests; Figure 3-2 is a more detailed schematic. The system consisted of a primary combustion chamber (rotary-kiln incinerator) with a screw feeder, a secondary combustion chamber, a water quench for the kiln ash, and a gas-conditioning tower. The purpose of the gas-conditioning tower (a water cooling tower) was to cool the combustion gases to between 600° and 800°F to allow for stack sampling. An adjustable-throat venturi scrubber, a cyclonic-flow water separator, and a fume incinerator [required by the Oklahoma State Department of Health (OSDH) for all tests involving hazardous waste] were also included in the configuration. All process monitoring and sampling during the pilots test were conducted upstream of the venturi scrubber.

The minimum heat throughput of the rotary-kiln incineration system (including waste and natural gas supplementary fuel) is 2 million Btu/h; the maximum is 3 million Btu/h. The waste feed rate was controlled by manually adding a measured quantity of waste into the screw feeder over a specified time interval. The kiln provided a 1-hour solids residence time at 0.25 rpm and a 0.5-hour residence at 0.5 rpm. The rotary kiln, whose dimensions were a nominal 5-ft o.d. x 15 ft long, was fitted with firing and discharge hoods. The firing hood was fitted with a burner and screw conveyor. The discharge hood was fitted with a flue-gas outlet, dry-ash sampling pipe, and wet-ash removal system. The kiln burner, which was a patented John Zink forced-draft DBY-03 model designed to fire gas, was fitted with a natural gas pilot light.

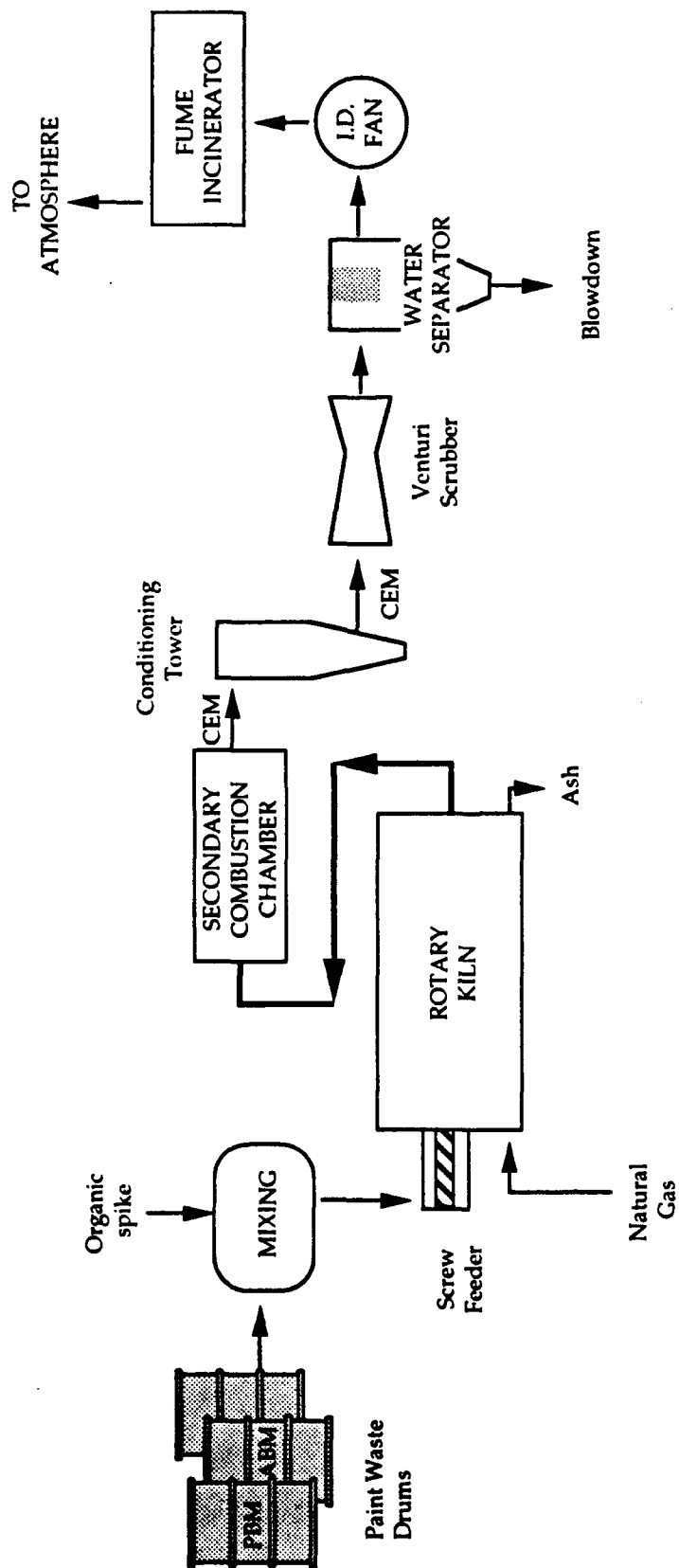


Figure 3-1. Diagram of the John Zink Co. Rotary Kiln System

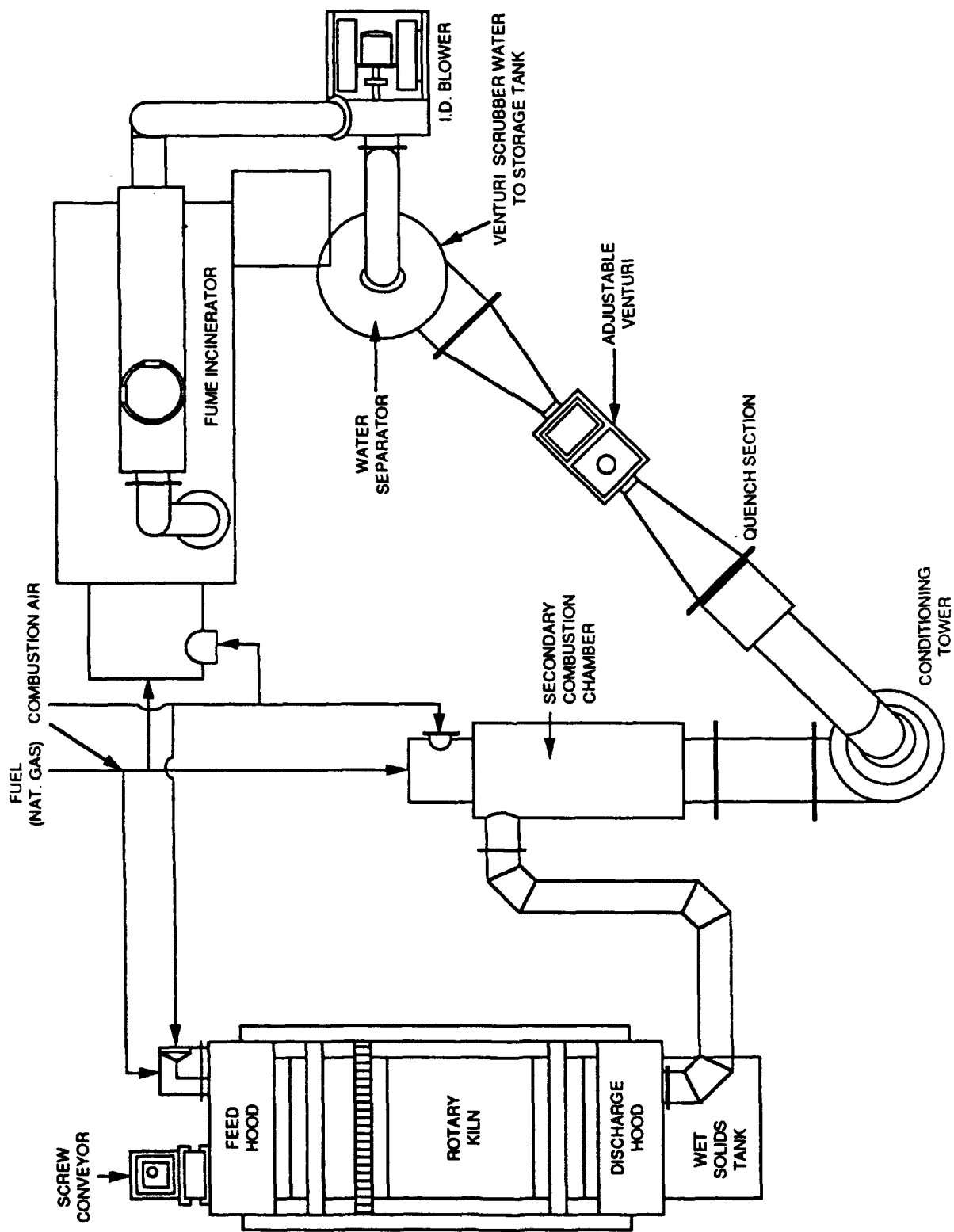


Figure 3-2. Rotary kiln incinerator configuration for solids.



The horizontal secondary combustion chamber, whose dimensions were a nominal 4.5-ft o.d. x 10 ft long, was fitted with a John Zink DBY-03 burner. The secondary combustion chamber provided a flue-gas residence time of 2.2 seconds at 2000°F (design residence time is 2.4 seconds at 2200°F).

The venturi scrubber design allowed adjustment of the venturi throat to maintain a selected operating pressure drop while the primary combustion system was in operation. The venturi contacted the flue gas with high-velocity water streams positioned at its throat in a direction normal to the flue-gas flow. The saturated flue gas and water-encapsulated particulates discharged into the water separator vent stack. The vertical water separator, whose dimensions were a nominal 5-ft o.d. x 10 ft high, imparted a radial flow to the flue gas. This radial flow caused separation of the water-encapsulated particulates from the flue gas. The water separator also served as a reservoir for the venturi scrubber water.

The induced-draft blower (New York Blower Company Model 26125) was used to provide a negative draft throughout the combustion system. The final fume incinerator was designed to fire natural gas at a maximum rate of 10 million Btu/h and to operate at temperatures exceeding 1500°F in the presence of excess combustion air.

### 3.2 INSTRUMENTATION AND CONTROLS

The rotary-kiln incineration system was equipped with multiple temperature-, pressure-, and flow-measuring devices, which were monitored by plant operators and engineers. The following parameters were measured with the instrumentation listed:

- ° Kiln and secondary combustion chamber operating temperatures: Type K thermocouples
- ° Stack gas temperature: Type K thermocouple
- ° Kiln pressure: Inclined manometer
- ° Kiln and secondary combustion chamber natural gas flow rates: Brooks Rotameter Model R-10M-25-3 with a Model 10-RS64 float
- ° Kiln and secondary combustion chamber natural gas pressures: Bourdon tube-type pressure gauge

- ° Kiln and secondary combustion chamber combustion air flow rates:  
Orifice meters
- ° Percent oxygen in kiln and secondary combustion chamber flue gases:  
On-line Teledyne meter
- ° Venturi pressure drop: Water-filled manometer
- ° Venturi makeup water rate: Brooks rotameter Model R-12M-25-4 with a 12-RS21 float
- ° Venturi recirculation water rate: Two Brooks Model R-10M-25-3 rotameters with 10-RV64 floats, aligned in parallel
- ° Venturi recirculation water pressure: Bourdon tube-type pressure gauge

Temperatures were controlled by changing the supplementary fuel feed rate and/or the combustion air flow rate or by adding steam. Supplementary fuel and combustion air were controlled by manually operated valves. Other system performance monitoring routinely conducted by the John Zink Co. consisted of continuous monitoring of temperature and of  $O_2$ , CO,  $CO_2$ ,  $SO_2$ , and  $NO_x$  in the stack gases exiting the OSDH-required test system fume incinerator.

## SECTION 4

### INCINERATION TEST PROGRAM

#### 4.1 EXPERIMENTAL PROCEDURES AND VARIABLES

Table 4-1 presents the test matrix for the pilot-scale evaluations. Four tests with different operating conditions (temperatures and kiln residence times) were conducted. Each test consisted of two 2-hour runs. The operating conditions investigated were temperatures in the kiln and secondary combustion chamber and the residence time of waste in the kiln (which was varied by changing the kiln rotation rate). The kiln operating temperatures investigated were 1500° and 1800°F. The secondary combustion chamber temperatures were 1600° and 2000°F for the low- and high-temperature tests, respectively. Two tests with residence times of 30 and 60 minutes were conducted for each of the two kiln operating temperatures, which yielded a total of four tests.

TABLE 4-1. TEST MATRIX FOR PAINT WASTE INCINERATION

Parameter	Test No.			
	1	2	3	4
Number of runs	2	2	2	2
Length of run, hours	2	2	2	2
Waste feed rate (dry), lb/h	195	195	195	195
Temperature in kiln, °F	1500	1500	1800	1800
Temperature in secondary combustion chamber, °F	1600	1600	2000	2000
Residence time, min	30	60	30	60
Kiln rpm	0.5	0.25	0.5	0.25

A total of 12 drums of ABM and 9 drums of PBM were transported from the Letterkenny Army Depot in Chambersburg, Pennsylvania, to the John Zink Co. facility in Tulsa, Oklahoma. Paint waste was fed to the kiln at a rate of 195 lb/h (dry). During each run, the waste tested consisted of equal portions (by weight) of spent plastic and agricultural blast media. The incinerator feed was manually mixed in a stainless steel, open-top pan approximately 32 ft<sup>2</sup> in area and 1 ft deep. A temporary enclosure was constructed to contain the dust formed when the dry media were handled. Tap water was added during mixing to prevent dusting, to allow feeding the waste to the kiln by screw conveyor, and to prevent the dry, fine-grained blast media from being blown immediately through the kiln by the combustion air. The moisture content of the spent blast media (after wetting) averaged 37 percent over all the tests.

For the test burns, a measured quantity of wetted, mixed blast media residue (6.5 lb dry wt.) was transferred from the drums to 5-gallon buckets. The paint waste was then spiked with organic compounds (chlorobenzene and 1,2-dichlorobenzene) to allow determination of the DRE's of both volatile and semivolatile organics. The spiking compound feed rates were 8.7 lb/h of chlorobenzene (volatile organic) and 13 lb/h of 1,2-dichlorobenzene (semivolatile organic), which represented 4 and 6 percent, respectively, of the total feed rate of combustible materials (not including the moisture content). Because these compounds are difficult to incinerate, they are ranked high on the EPA incinerability index;<sup>5</sup> thus, if the performance standard of 99.99 percent DRE is met for these compounds, other volatile and semivolatile compounds would also be destroyed under the same incineration conditions. The mixed waste (PBM, ABM, water, and spiking compounds) was fed manually from each bucket into the kiln screw feeder on a continuous basis over a 2-minute period.

#### 4.2 FEED AND ASH SAMPLING

A plastic scoop was used to take a composite sample from each drum of feed material. These samples were then combined in a stainless steel bowl in ratios reflecting the characteristics of the material fed to the incinerator over each 2-hour run. For example, if one-third of one drum, a full second

drum, and one-third of a third drum were used during a particular run, samples from these drums would be combined in a 1:3:1 ratio, reflecting the amount of a particular drum used. One composite sample was taken for each of the eight runs, and each composite sample was analyzed for metals and organic compounds. Proximate and ultimate analyses were also conducted on the paint waste.

Dry kiln ash was sampled from a port near the bottom of the kiln discharge hood before its contact with the quench water. Samples were collected approximately every 30 minutes, beginning at the time the first ash after the start of a particular run exited the kiln (accounting for the residence time) and ending when the last ash of the run exited the kiln (again, accounting for the residence time). These ash samples were then combined into a single composite sample for each run. Samples of the kiln ash were analyzed for metals and organic compounds. The ash was also subjected to the TCLP extraction, and the extract was analyzed for metals and organic compounds.

#### 4.3 ATMOSPHERIC EMISSION TESTING

Atmospheric emission tests were conducted downstream from the secondary combustion chamber and immediately prior to the venturi scrubber pollution control system. A water-spray tower was inserted between the secondary combustion chamber and the emission sampling location to cool the off-gases to between 600° and 800°F. During each test run, the following sampling trains and subsequent analyses were conducted:

- ° Volatile organic sampling train (VOST) - Surrogate volatile organic compound (chlorobenzene)
- ° Modified Method 5 (MM5) sampling train - Surrogate semivolatile organic compound (1,2-dichlorobenzene), particulates, and HCl
- ° Metals sampling train - Antimony, arsenic, barium, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, vanadium, and zinc
- ° Particle size distribution
- ° Integrated bag sample - O<sub>2</sub>, CO<sub>2</sub>
- ° Continuous emission monitors (CEM's) - NO<sub>x</sub>, SO<sub>2</sub>, O<sub>2</sub>, CO<sub>2</sub>, and CO

Table 4-2 summarizes the sampling and analytical protocol followed during this test program. This program was designed to characterize emissions from the incineration of two specific types of paint waste mixed with surrogate organic compounds and to provide design data for pollution-control purposes.

#### 4.3.1 Sample Locations

Figure 4-1 depicts the John Zink incinerator unit and the sampling locations (noted as A and B). The CEM for  $O_2$ ,  $CO_2$ , and CO was conducted at Location A, immediately after the secondary combustion chamber. Temperature measurements were also continuously recorded at this location with a thermocouple and strip-chart recorder. Sampling Location B was used for all other data measurements. Sampling at Location B was conducted in a 12-inch-i.d. round duct. Two sampling ports, 90 degrees offcenter, were located approximately 6 duct diameters downstream and 7 duct diameters upstream from the nearest flow disturbances in the duct. The Modified Method 5 (MM5) and metals sampling trains were run simultaneously in these two ports. A total of 12 sampling points was used to traverse the cross-sectional area of the duct at this location. Two additional sampling ports located upstream from the MM5/metals ports were used for the VOST and the CEM sample probe ( $NO_x/SO_2$ ). Figure 4-2 depicts the location of the sampling ports used for this program.

#### 4.3.2 Sampling and Analysis Procedures

Volatile organic emissions (chlorobenzene) were measured in accordance with the VOST protocol.<sup>6</sup> The sampling train consisted of a heated glass probe, a pair of water-cooled condensers, and a pair of sorbent traps in series. The first sorbent trap contained approximately 1.6 g of Tenax TC; the second contained approximately 1 g of Tenax TC and 1 g of activated charcoal. Each sample was collected at a constant rate of 0.5 liter per minute over a 40-minute period. Three 40-minute samples were collected during each 2-hour test run. Condensate collected in the sampling train was recovered after each 2-hour test run and analyzed for volatile organic content.

TABLE 4-2. SUMMARY OF ATMOSPHERIC EMISSION TESTING

Sample stream identification	Access	Analytical parameter	Sampling equipment	General procedure/- frequency	Reference methods	Analyses	Analytical method	Reference method	Analytical frequency
Conditioned stack gas (prior to venturi scrubber) (Sample Port B)	ports	Volatile organics	VOST	Triplicate single-point sample pairs-40 minutes per pair	0030 and 5040, SW-846, 3rd Edition	Volatile POHC's: (chlorobenzene)	GC/MS (VOST)	SW846 - 3rd Edition, Methods 0030 and 5040	18 pairs, 3 condensates
		Flue gas Flow/temperature	EPA 2	Concurrent with each particulate/metals test	EPA 2	Semi-volatile POHC's (1,2-dichlorobenzene)	GC/MS	SW846 - 3rd Methods 0010 and 8270	
		Semi-volatile organics	Modified Method 5	Triplicate integrated 3-hour sample run	0010 and 8270 (SW-846)	Semi-volatile POHC's (1,2-dichlorobenzene)	GC/MS	SW846 - 3rd Method 0010 and 8270	
		Particulate	Modified Method 5	Triplicate integrated 3-hour sample run	EPA 5	Particulate	Gravimetric	EPA 5	8
		HCl	Modified Method 5	Triplicate integrated 3-hour sample run	EPA 300	HCl	Ion chromatography	EPA 300	8
		Metals	EPA 12 sample train (modified)	Triplicate integrated 2-hour sample run	EPA 12	Metals	ICP <sup>a</sup> , atomic absorption	SW846 M3050 and 3020 (digestion) M7060 (arsenic) M7421 (lead) M7740 <sub>b</sub> (selenium) M101A <sub>b</sub> (mercury) M6010 (all others)	8
		O <sub>2</sub>	EPA 3	Integrated bag sample collected during each test particulate/- metals test	EPA 3	O <sub>2</sub>	Orsat	EPA 3	8
		CO <sub>2</sub>	EPA 3			CO <sub>2</sub>	Orsat	EPA 3	8
		Nitrogen oxide	EPA 7F	Continuously monitored during test program	EPA 7F	NO <sub>x</sub>	Chemiluminescent	EPA 7F	Continuous
		Sulfur dioxide	EPA 6C	Continuously monitored during test program	EPA 6C	SO <sub>2</sub>	Pulsed fluorescent	EPA 6C	Continuous
		Particle sizing	Anderson impactor	Two tests per condition, total		Particle size	Gravimetric		7

(continued)

TABLE 4-2 (continued)

Sample stream identification	Access	Analytical parameter	Sampling equipment	General procedure/- frequency	Reference methods	Analysis	Analytical method	Reference method	Analytical frequency
Stack gas (in secondary combustion chamber) (sample Port A)	ports	O <sub>2</sub>	EPA 3A	Continuously monitored during test program	EPA 3A	O <sub>2</sub>	Zirconium	3A	Continuous
		CO <sub>2</sub>	EPA 3A	Continuously monitored during test program	EPA 3A	CO <sub>2</sub>	NDIR	3A	Continuous
		CO	EPA 10	Continuously monitored during test program	EPA 10	CO	NDIR	10	Continuous

<sup>a</sup> Inductively coupled plasma spectroscopy.

<sup>b</sup> Method given in 40 CFR 61, Appendix B - Test Methods. July 1988.



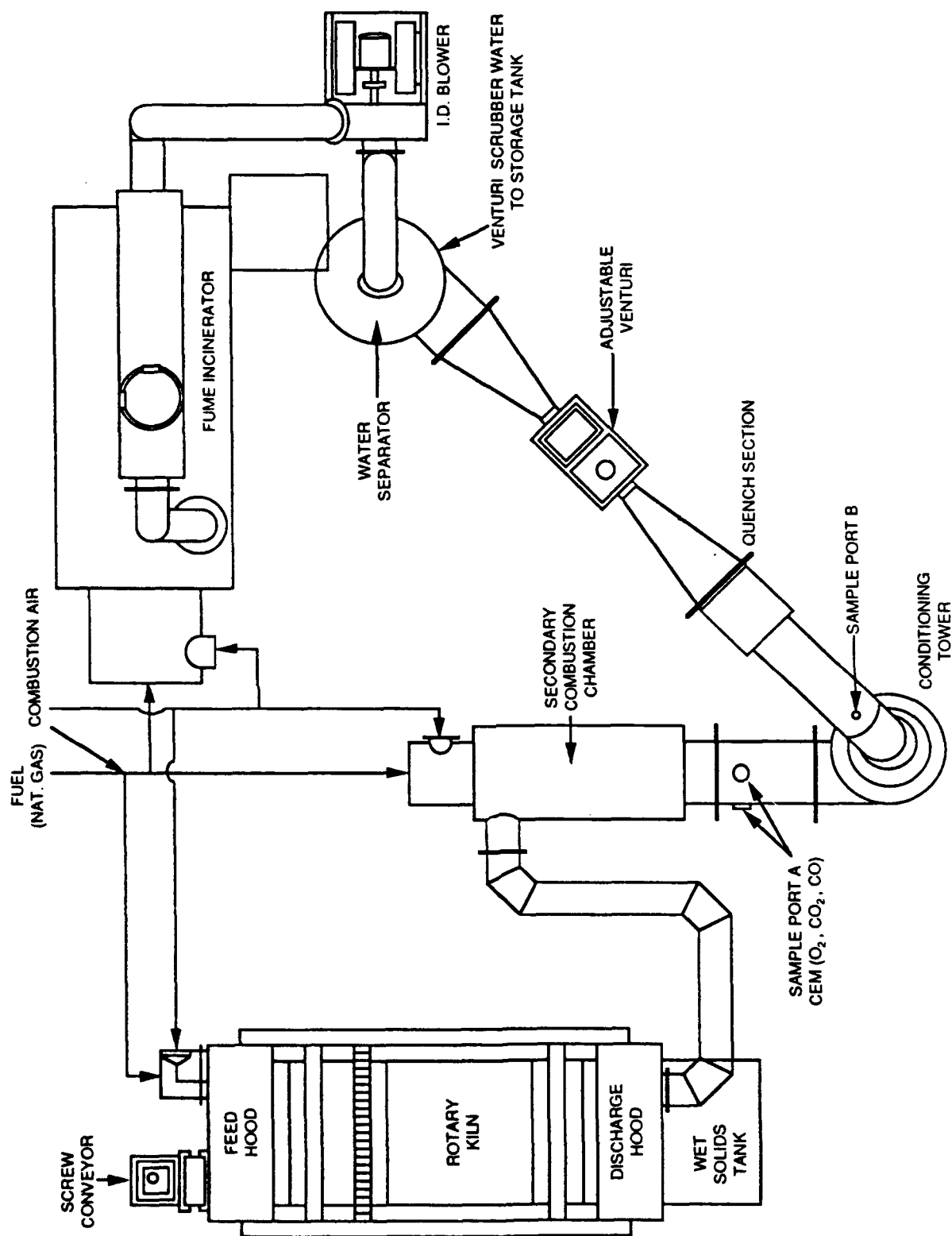


Figure 4-1 Sampling port locations.

SAMPLE POINT NO.	DISTANCE FROM OUTSIDE OF NIPPLE, in.
1	6-1/4
2	7-1/2
3	9-1/4
4	14-1/4
5	16
6	17-1/4

# CROSS SECTION

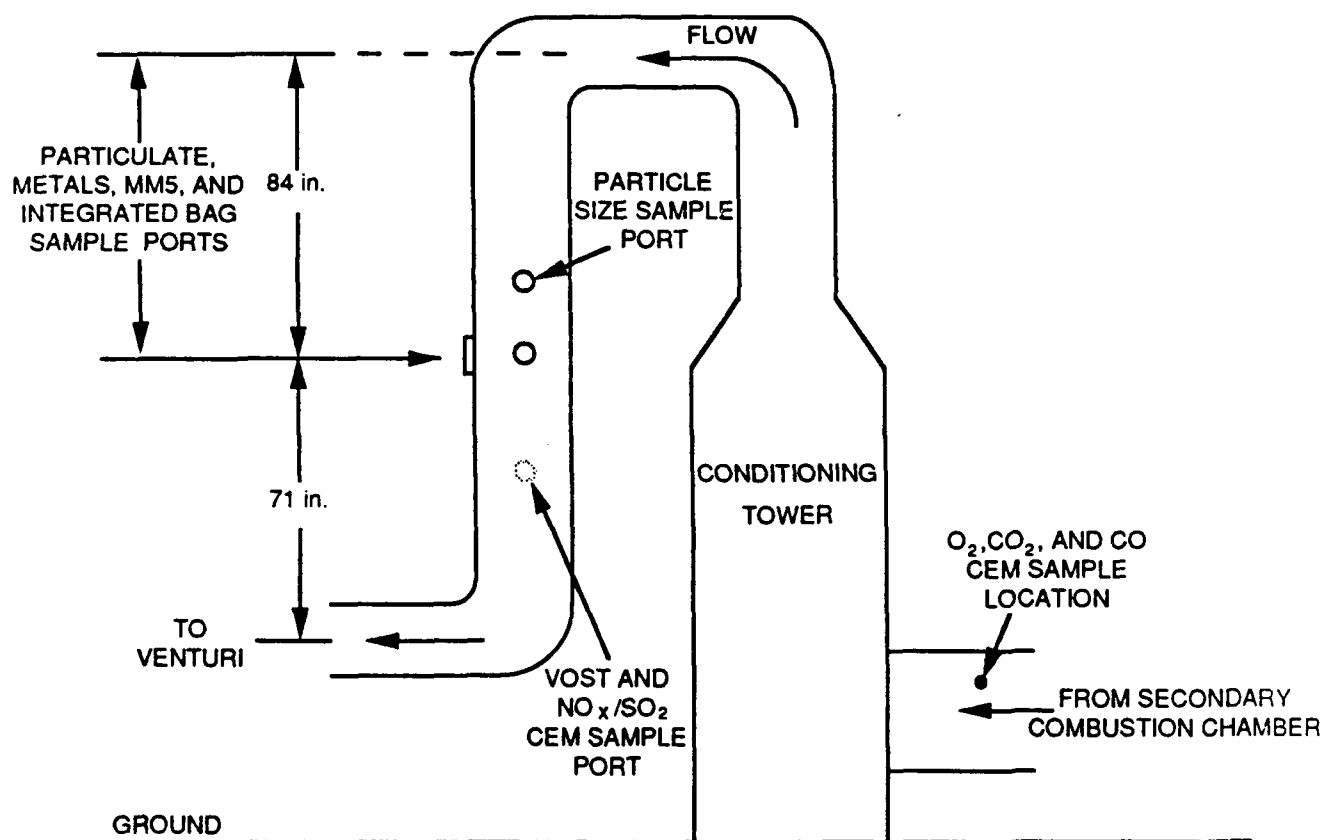
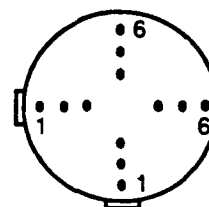


Figure 4-2. Stack gas sample location.

The MM5 sampling train was used to measure semivolatile organic (1,2-dichlorobenzene), particulate, and HCl emissions. This sampling train consisted of a stainless steel nozzle, a heated glass-lined probe, a heated glass-fiber particulate filter, an XAD-2 sorbent trap, and a series of impingers. The filter and methylene chloride rinse of the nozzle, probe, and connecting glassware were recovered and analyzed gravimetrically for particulates in accordance with MM5 procedures.<sup>7</sup> Initially, the first two impingers were empty, the following two impingers contained 100 ml each of 0.1 N NaOH, and the fifth impinger contained silica gel. The impingers were weighed before and after each test to determine the stack-gas moisture content. Each impinger was then recovered and placed in a single container. Aliquots were taken for determination of HCl content by ion chromatography. Upon completion of the particulate and HCl analyses, sample fractions were extracted and combined into a single extract for gas chromatograph/mass spectrometer (GC/MS) analysis for 1,2-dichlorobenzene by EPA (SW 846 Method 8270) procedures.<sup>7</sup>

A modified EPA Method 12 sampling train was used to collect metals emissions. This train consisted of a stainless steel sampling nozzle, a heated glass-lined probe, a heated filter, and a series of impingers containing 0.1 N nitric acid ( $\text{HNO}_3$ ) and potassium permanganate ( $\text{KMnO}_4$ ). All MM5 and metals samples were collected isokinetically by traversing the cross-sectional area of the stack. Probe rinse, filter, and impinger solution fractions ( $0.1 \text{ N HNO}_3$ ) were combined and digested into a single sample and analyzed for metals. The  $\text{KMnO}_4$  solution was analyzed for mercury only. This sampling train ran concurrently with the MM5 sampling train for a total test time of 2 hours.

Flue-gas flow rate, temperatures, moisture content, and composition ( $\text{O}_2$  and  $\text{CO}_2$ ) were determined in conjunction with each MM5 and metals emission test by procedures outlined in EPA Methods 1 through 4.<sup>8</sup>

The  $\text{SO}_2$  and  $\text{NO}_x$  emissions were measured by EPA Methods 6C and 7E, respectively.<sup>8</sup> Sample gas was continuously extracted with a Teflon sampling pump and line passed through a filter/condenser conditioning system and, finally, to the  $\text{NO}_x$  and  $\text{SO}_2$  continuous emission monitors for analysis. The  $\text{NO}_x$  analyzer had a chemiluminescent detection system, and the  $\text{SO}_2$  analyzer had a pulsed fluorescent-type detection system. Each analyzer was calibrated

with Master Gas Certified Standards ( $\pm 2$  percent of label values), and results were charted on a Heath strip-chart recorder. Data were recorded during the MM5/metals sampling blocks.

At the secondary combustion chamber outlet,  $O_2$ ,  $CO_2$ , and CO were continuously measured by EPA Methods 3A (for  $O_2$ ) and 10 (for  $CO_2$  and CO).<sup>8</sup> Sample gas was continuously extracted with a Teflon sampling pump and line passed through a quartz glass filter/condenser conditioning system and, finally, to the CEM's for analysis. The  $O_2$  analyzer had a zirconium cell detector, and the  $CO_2$ /CO analyzers had nondispersive infrared (NDIR) detectors. Sample results were permanently recorded on Heath strip-chart recorders.

The particle sizing procedures followed guidelines in the EPA's procedures manual for inhalable particulate sampling operations.<sup>9</sup> An Anderson Mark III multistage impactor was used to determine particulate particle size distribution. Each impactor consisted of eight impaction stages followed by a backup filter. In these tests, glass-fiber filter media were used. Samples were collected at one point within each duct, which represented the average velocity head temperature.

Each test was conducted in accordance with the procedures described in the Mark III operations manual supplied by the manufacturer. Isokinetic sampling rates were set initially, and constant cut-point characteristics were maintained throughout the sampling period. For each individual sample, a size distribution curve was established, which represented the total weight percentage of particulate matter smaller than the indicated aerodynamic particle diameter in micrometers. Testing was performed at the conclusion of the MM5/metals sampling blocks.

All air sampling and analysis methods included by reference in this report were conducted in accordance with procedures contained in the following:

1. Standards of Performance for New Stationary Sources, EPA Reference Methods, 40 CFR 60, Appendices A and B.
2. Sampling and Analysis Methods for Hazardous Waste Combustion. Arthur D. Little, Inc. EPA-600/8-84-002, February 1984.
3. Test Methods for Evaluating Solid Wastes. Physical/Chemical Methods, EPA SW 846, 3rd ed. November 1986.

4. Annual Book of ASTM Standards.
5. Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020, 1979.
6. Validation of the Volatile Organic Sampling Train (VOST) Protocol. EPA-600/SA-86/014. April 1986.

#### 4.4 COLLECTION OF OPERATIONAL DATA

Incineration operational data were collected throughout each run to document test conditions. During each run, John Zink Co. and PEI personnel recorded the following data at 30-minute intervals: rotary-kiln incinerator, secondary combustion chamber, and fume incinerator temperatures; percent oxygen in gases exiting the kiln and secondary combustion chamber; flow rates of combustion air to the kiln and secondary combustion chamber; and kiln pressure. Many of these parameters (e.g., percent oxygen and combustion gas temperatures) were also continuously monitored as part of the atmospheric emissions testing detailed in Subsection 4.3.

## SECTION 5

### PRESENTATION OF TEST BURN DATA

#### 5.1 CHARACTERIZATION OF PAINT WASTE FEED

One composite feed sample was collected for each of the eight incinerator runs. All samples were collected before the surrogate spiking compounds were added; therefore, the results represent values for ABM, PBM, and water used for wetting (unless a dry basis is indicated) in the mixture. Results given on a dry basis were calculated with the analyzed moisture content and reflect the mixture of ABM and PBM before water or spiking compounds were added.

The results of the proximate and ultimate analyses of the feed material are presented in Tables 5-1 and 5-2, respectively. The average heating value of the dry waste was 7680 Btu/lb; after the water was added (before the spiking compounds), the resulting average 37.25 percent moisture content of the feed material reduced the heating value to 4820 Btu/lb. The ash content (dry basis) ranged from 6.5 to 14.3 percent and averaged 11 percent. The elements of concern with regard to air pollution--sulfur, nitrogen, and chlorine--averaged 0.11, 12.4, and 0.09 percent, respectively.

Table 5-3 presents the concentration of metals in the feed on a wet and dry basis. Table 5-4 presents the total amount of metals (in pounds per hour) entering the kiln in the feed; these values were calculated by using the concentration of metals in the dry feed and a dry feed rate of 195 lb/h. Lead and chromium are the primary metals of environmental concern that render the media residue hazardous. Lead concentrations ranged from 1800 to 8320 ppm (average of 5070 ppm), and chromium from 595 to 2340 ppm (average of 1470 ppm). Barium was also present in significant amounts, with an average concentration of 504 ppm.

Four of the eight feed samples were analyzed for organics. Table 5-5 presents the results for the wet feed material (without spiking compounds) and for the dry feed material. The only compounds found with any concentrations greater than 1 ppm on a dry basis were methylene chloride (0.28 to

TABLE 5-1. PROXIMATE ANALYSIS OF FEED MATERIAL

Parameter	Test Run Number							Average
	1A	1B	2A	2B	3A	3B	4A	4B
<b>WET FEED</b>								
Moisture, %	40.64	41.36	41.21	34.84	35.93	41.24	36.44	26.37
Volatile matter, %	42.54	39.62	42.23	47.7	46.45	40.93	45.71	50.46
Fixed Carbon, %	10.15	10.95	9.79	13.2	12.16	10.81	11.45	12.63
Ash, %	6.67	8.07	6.77	4.26	5.46	7.02	6.4	10.54
Sulfur, %	0.05	0.06	0.06	0.08	0.08	0.09	0.07	0.07
Heating value, Btu/lb	4692	4404	4427	5128	4985	4536	4846	5511
<b>DRY BASIS</b>								
Volatile matter, %	71.67	67.56	71.83	73.2	72.5	69.65	71.91	68.53
Fixed carbon, %	17.1	18.68	16.65	20.26	18.98	18.4	18.02	17.16
Ash, %	11.23	13.76	11.52	6.54	8.52	11.95	10.07	14.31
Sulfur, %	0.08	0.11	0.1	0.12	0.12	0.15	0.11	0.1
Heating value, Btu/lb	7905	7510	7530	7870	7780	7720	7625	7485
								70.86
								18.16
								10.99
								0.11
								7678

TABLE 5-2. ULTIMATE ANALYSIS OF FEED MATERIAL (DRY BASIS)  
(percent)

Element	Test Run Number								Average
	1A	1B	2A	2B	3A	3B	4A	4B	
Carbon	42.38	41.51	44.92	46.68	44.44	44.27	41.37	40.72	43.29
Hydrogen	5.56	5.3	5.49	5.97	5.22	5.24	5.13	5.06	5.37
Nitrogen	10.28	12.64	13.51	16.05	14.67	11.93	15.2	5.07	12.42
Chlorine	0.07	0.07	0.11	0.11	0.11	0.11	0.09	0.07	0.09
Oxygen	30.4	26.51	24.35	24.53	26.92	26.35	28.03	34.67	27.72



TABLE 5-3. CONCENTRATION OF METALS IN FEED  
[µg/g (ppm)]

Total metals	Test Run Number								Average
	1A	1B	2A	2B	3A	3B	4A	4B	
WET FEED									
Arsenic	1.5	1.8	1.8	1.2	1.0	1.3	2.9	8.4	2.5
Barium	288	430	394	147	341	388	300	187	309
Cadmium	89.3	73.8	58.8	75.0	49.2	49.2	62.9	73.2	66.4
Chromium	986	1370	1140	388	816	1170	797	506	897
Lead	2980	4880	4270	1170	2950	4330	2620	1500	3088
Mercury	<0.13 <sup>a</sup>	<0.13	<0.12	<0.12	<0.12	<0.14	<0.14	<0.13	0
Selenium	0.57	<0.08	0.65	0.93	1.7	0.79	1.1	<0.09	0.72
Silver	2.1	2.3	1.1	2.4	2.1	0.75	6.8	22.5	5.0
DRY BASIS									
Arsenic	2.5	3.1	3.1	1.8	1.6	2.2	4.6	11.4	3.8
Barium	485	733	670	226	532	660	472	254	504
Cadmium	0	126	100	115	76.8	83.7	99.0	99.4	106
Chromium	1660	2340	1940	595	1270	1990	1250	687	1467
Lead	5020	8320	7260	1800	4600	7370	4120	2040	5066
Mercury	<0.22	<0.22	<0.20	<0.18	<0.19	<0.24	<0.22	<0.18	0
Selenium	0.96	<0.14	1.1	1.4	2.7	1.3	1.7	<0.12	1.1
Silver	3.5	3.9	1.9	3.7	3.3	1.3	10.7	30.6	7.4

<sup>a</sup> < Indicates concentration of metal was below the specified detection limit.

TABLE 5-4. METALS IN FEED (DRY BASIS)  
(lb/h)

Total metals	Test Run Number							
	1A	1B	2A	2B	3A	3B	4A	4B
Arsenic	0.00049	0.00060	0.00060	0.00035	0.00031	0.00043	0.00090	0.00222
Barium	0.095	0.143	0.131	0.044	0.104	0.129	0.092	0.050
Cadmium	0.0293	0.0246	0.0195	0.0224	0.0150	0.0163	0.0193	0.0194
Chromium	0.324	0.456	0.378	0.116	0.248	0.388	0.244	0.134
Lead	0.98	1.62	1.42	0.35	0.90	1.44	0.80	0.40
Mercury	0.000043	0.000043	0.000039	0.000035	0.000037	0.000047	0.000043	0.000035
Selenium	0.000187	0.000027	0.000215	0.000273	0.000527	0.000254	0.000332	0.000023
Silver	0.00068	0.00076	0.00037	0.00072	0.00064	0.00025	0.00209	0.00597

TABLE 5-5. CONCENTRATION OF ORGANICS IN FEED  
[µg/kg (ppb)]

Compound results in µg/kg (ppb)	Wet Feed				Dry Feed			
	Test Run Number				Test Run Number			
	1A	2A	3A	4A	1A	2A	3A	4A
Methylene chloride	300	200	180	210	500	340	280	330
Acetone	1100	920	940	2400	1900	1600	1500	3800
Carbon disulfide	<25 <sup>a</sup>	<25	<25	<25	<40	<40	<40	<40
1,1,1-Trichloroethane	98	41	68	660	160	70	110	1000
4-Methyl-2-pentanone	800	2900	4000	2900	1300	4900	6200	4600
Ethyl benzene	<23 <sup>b</sup>	40	<25	33	<39	68	<40	52
Tetrachloroethane	<25	<8	<3	<4	<42	<14	<5	<6
Toluene	51	56	49	62	86	95	76	98
2-Butanone	270	400	500	570	460	680	780	900
Carbon tetrachloride	<25	<25	<25	<25	<40	<40	<40	<40
Chlorobenzene	43	92	76	190	72	160	120	300
Total xylenes	62	110	61	88	100	190	95	140
iso-Butanol	<250	<250	<250	<250	<400	<400	<400	<400
n-Butanol	<250	<250	<250	<250	<400	<400	<400	<400
Ethyl acetate	<25	<25	<25	<25	<40	<40	<40	<40
Ethyl ether	<50	<50	<50	<50	<80	<80	<80	<80
Trichlorofluoromethane	<50	<50	<50	<50	<80	<80	<80	<80
Trichlorotrifluoroethane	<25	<25	<25	<25	<40	<40	<40	<40
Trichloroethylene	<25	<25	<25	<25	<40	<40	<40	<40
Methanol	9000	6000	6700	23000	15000	10000	10000	36000
Cyclohexanone	<100	<100	<100	<100	<165	<165	<165	<165
Nitrobenzene	<330	<330	<330	<330	<540	<540	<540	<540
2-Methylphenol	<330	810	340	340	<560	1400	530	540
3-Methylphenol	<330	<330	<330	<330	<540	<540	<540	<540
4-Methylphenol	1100	<330	2100	2100	1900	<560	3300	3300
Pyridine	<660	<660	<660	<660	<1100	<1100	<1100	<1100
1,2-Dichlorobenzene	<180	520	<430	2000	<300	880	<670	3100

<sup>a</sup> < indicates concentration of compound was below the specified detection limit.

<sup>b</sup> . indicates estimated value. Mass spectral data indicate the presence of a compound that meets identification criteria, but the result is less than the specified detection limit.

0.50 ppm), acetone (1.5 to 3.8 ppm), 4-methyl-2-pentanone (0.3 to 6.2 ppm), methanol (10 to 36 ppm), 2-methylphenol (nondetectable to 1.4 ppm), 4-methylphenol (nondetectable to 3.3 ppm), and 1,2-dichlorobenzene (0.3 to 3.1 ppm).

## 5.2 KILN ASH CHARACTERIZATION

Table 5-6 presents the concentration of metals present in the seven samples of incinerator kiln ash. During Test Run 3A, essentially no kiln ash was generated and a sufficient quantity to perform an analysis was not collected. Metals present in the highest concentrations in the kiln ash were lead, barium, and chromium. Lead concentrations ranged from 161 to 2915 ppm; barium, from 475 to 2140 ppm; and chromium, from 132 to 982 ppm.

Table 5-7 presents the concentrations of organic compounds found in the ash samples. In most cases, organics were not detected. Methylene chloride and acetone, however, were present. Methylene chloride concentrations ranged from 130 to 5400 ppb and exceeded 500 ppb in only the two runs of Test 2; acetone ranged from 140 to 6400 ppb and, again, Test 2 showed higher concentrations. The volatile spiking compound chlorobenzene was found in low quantities in the ash during Test Runs 1B (190 ppb) and 3B (39 ppb); its presence was also detected in the ash during Test Run 4A (estimated at 8 ppb). The semivolatile spiking compound 1,2-dichlorobenzene was detected at 710 ppb in the ash during Test Run 1A and was nondetectable in the ash during Test Run 4B. In the other five ash samples, 1,2-dichlorobenzene was identified. Its concentration, however, was less than the specified detection level, and ranged approximately from 97 to 430 ppb in these samples.

Samples of the incinerator ash were subjected to the TCLP. Table 5-8 presents the concentration of metals in the extracts. Test Run 3A, which had a kiln temperature of 1800°F and 60-minute residence time, was the only test that produced ash exceeding the TCLP criteria. The TCLP extract of this ash sample contained cadmium in a concentration of 7.1 ppm (TCLP limit = 1 ppm) and 32 ppm chromium (TCLP limit = 5 ppm). Concentrations of lead and silver in the TCLP extract of this sample approached the TCLP limits of 5 ppm for each.

TABLE 5-6. CONCENTRATION OF METALS IN ASH SAMPLES  
[µg/g (ppm)]

Total metals	Test Run Number						
	1A	1B	2A	2B	3B	4A	4B
Arsenic	18.4	14.3	19.5	28.4	9.5	15.8	0.68
Barium	1340	2940	2700	725	1290	713	237
Cadmium	7.1	5.7	10.3	6.2	4.9	2.5	0.81
Chromium	674	1290	1150	401	477	202	61.6
Lead	874	1830	4780	1050	643	269	52.9
Mercury	<0.13 <sup>a</sup>	<0.13	<0.14	<0.14	0.31	<0.13	<0.13
Selenium	<0.10	<0.11	<0.11	0.67	<0.08	<0.08	<0.08
Silver	32.3	19.1	34.8	62.3	3.5	0.54	<0.43

<sup>a</sup> < indicates concentration of metal was below the specified detection limit.

TABLE 5-7. CONCENTRATION OF ORGANIC COMPOUNDS IN ASH SAMPLES  
[µg/g (ppm)]

Compound	Test Run Number						
	1A	1B	2A	2B	3B	4A	4B
Methylene chloride	300	440	5200	5400	220	140	130
Acetone	140	240	6400	6400	740	280	200
Carbon disulfide	<25 <sup>a</sup>	<25	<600	<600	<25	<25	<25
1,1,1-Trichloroethane	<25	<25	<600	<600	<25	<25	<25
4-Methyl-2-pentanone	<50	<50	<1200 <sup>b</sup>	<1200	<50	<50	<50
Ethyl benzene	<25	<25	*120 <sup>b</sup>	<600	*7	<25	<25
Tetrachloroethane	<25	<25	<600	<600	<25	<25	<25
Toluene	<25	230	<600	<600	*20	*4	<25
2-Butanone	<50	<50	<1200	<1200	<50	<50	<50
Carbon tetrachloride	<25	<25	<600	<600	<25	<25	<25
Chlorobenzene	<25	190	<600	<600	39	*8	<25
Total xylenes	<25	<25	<600	<600	<25	<25	<25
Iso-Butanol	<50	<50	<50	<50	<50	<50	<50
n-Butanol	<50	<50	<50	<50	<50	<50	<50
Ethyl acetate	<25	<25	<600	<600	<25	<25	<25
Ethyl ether	<50	<50	<1200	<1200	<50	<50	<50
Trichlorofluoromethane	<50	<50	<1200	<1200	<50	<50	<50
Trichlorotrifluoroethane	<25	<25	<600	*130	*9	<25	<25
Trichloroethylene	<25	<25	<600	<600	<25	<25	<25
Methanol	<300	<300	<300	<300	<300	<300	<300
Cyclohexanone	<50	<50	<50	<50	<50	<50	<50
Nitrobenzene	<660	<660	<660	<660	<660	<660	<660
2-Methylphenol	<660	<660	<660	<660	<660	<660	<660
3-Methylphenol	<660	<660	<660	<660	<660	<660	<660
4-Methylphenol	<660	<660	<660	<660	<660	<660	<660
Pyridine	<1300	<1300	<1300	<1300	<1300	<1300	<1300
1,2-Dichlorobenzene	710	*430	*97	*190	*130	*220	<660

<sup>a</sup> < indicates concentration of compound was below the specified detection limit.

<sup>b</sup> \* Indicates estimated value. Mass spectral data indicate the presence of a compound that meets identification criteria, but the result is less than the specified detection limit.

TABLE 5-8. CONCENTRATION OF METALS IN TCLP EXTRACTS  
[µg/g (ppm)]

Total metals	Test Run Number						TCLP regulatory level	
	1A	1B	2A	2B	3B	4A		4B
Arsenic	<0.002 <sup>a</sup>	<0.002	<0.002	<0.002	0.006	0.03	<0.002	5.0
Barium	0.6	0.66	0.27	2	1.5	1.3	2.4	100
Cadmium	0.03	0.02	0.01	0.009	7.1	0.02	0.02	1.0
Chromium	<0.002	0.09	<0.002	<0.002	32	0.09	0.09	5.0
Lead	0.28	4.6	2.8	0.17	4.2	1.2	0.15	5.0
Mercury	<0.0003	<0.0003	<0.0003	<0.0003	<0.0003	0.0008	<0.0003	0.2
Selenium	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	1.0
Silver	0.13	0.06	0.01	0.07	3.1	<0.009	0.03	5.0

<sup>a</sup> < indicates concentration of metal was below the specified detection limit.

Concentrations of organic compounds in the ash TCLP extracts are presented in Table 5-9. With the exception of methylene chloride and acetone, no organics were detected in the extracts. As shown in Table 5-9, detection limits of all the organic compounds were well under the land disposal treatment standards. Methylene chloride, present in the extracts at concentrations ranging from 19 to 140 ppb, and acetone, with a concentration range of 39 to 180 ppb, were also present in levels considerably below land disposal treatment standards. Neither of the surrogate spiking compounds, both of which had a detection limit of 10 ppb, was detected.

### 5.3 ATMOSPHERIC EMISSIONS TEST RESULTS

The following subsections present the results of the atmospheric emissions test program.

#### 5.3.1 Summary of Flue Gas Conditions

Flue gas data measured by Modified Method 5 (MM5) and metals trains, which were run simultaneously at two sampling ports 90 degrees off center from each other, are summarized in Tables 5-10 and 5-11. The MM5 train data were used in all subsequent mass rate calculations for DRE determination, particulates, HCl, and CEM's. The metals train data were used to calculate metals mass emission rates. Flue gas flow rates are reported in actual cubic feet per minute (acfm) at observed stack conditions and dry standard cubic feet per minute (dscfm) at 68°F, 29.92 in.Hg, and zero percent moisture. Measurements of flow rate, moisture content, and temperature varied less than 10 percent between sampling train measurements (MM5 and metals trains).

Flue gas flow rates were fairly consistent; they ranged between 700 and 950 dscfm. Flue gas temperatures ranged between 500° and 600°F. The average moisture content was about 43 percent by volume.

Because the gas stream appeared to be saturated, two determinations were made. The first involved a volumetric determination of the amount of water collected during each test, and the second involved calculation of the moisture content with the vapor pressure of water at the measured stack temperature and pressure. In each case, the lower value was reported as specified in EPA Method 4.<sup>8</sup>



TABLE 5-9. CONCENTRATION OF ORGANIC COMPOUNDS IN ASH TCLP EXTRACTS  
[µg/kg (ppb)]

Compound results in µg/kg (ppb)	Test Run Number				Land disposal/ treatment standards		
	1A	1B	2A	2B	3B	4A	
Methylene chloride	28	120	22	19	140	90	960
Acetone	44 <sup>a</sup>	160	39	42	180	110	590
Carbon disulfide	<10 <sup>a</sup>	<10	<10	<10	<10	<10	4810
1,1,1-Trichloroethane	<10	<10	<10	<10	<10 <sup>b</sup>	<10	410
4-Methyl-2-pentanone	<20	130	<20	<20	* 15 <sup>b</sup>	<20	330
Ethyl benzene	* 1	* 2	* 1	* 2	<5	<10	53
Tetrachloroethane	<10	<10	<10	<10	<10	<10	50
Toluene	<10	* 3	<10	<10	<10	<10	330
2-Butanone	<20	43	<20	<20	* 8	<20	750
Carbon tetrachloride	<10	<10	<10	<10	<10	<10	960
Chlorobenzene	<10	<10	<10	<10	<10	<10	50
Total xylenes	<10	* 2	<10	<10	<10	<10	150
Methanol	<300	<300	<300	<300	<300	<300	750
Cyclohexanone	<20	<20	<20	<20	<20	<20	750
Nitrobenzene	<10	<10	<10	<10	<10	<10	125
2-Methylphenol	<10	<10	<10	<10	<10	<10	-
3-Methylphenol	<10	<10	<10	<10	<10	<10	-
4-Methylphenol	<10	<10	<10	<10	<10	<10	-
Pyridine	<20	<20	<20	<20	<20	<20	300
1,2-Dichlorobenzene	<10	<10	<10	<10	<10	<10	125

<sup>a</sup> < indicates concentration of compound was below the specified detection limit.

<sup>b</sup> \* indicates estimated value. Mass spectral data indicate the presence of a compound that meets identification criteria, but the result is less than the specified detection limit.

TABLE 5-10. SUMMARY OF FLUE GAS CONDITIONS - MODIFIED METHOD 5 TRAIN<sup>a</sup>

Test run No.	Date (1988)	Time (24-h)	Volumetric flow rate		Temperature, °F	Moisture content, %	Gas composition		
			acfm <sup>b</sup>	dscfm <sup>c</sup>			O <sub>2</sub> , % <sup>d</sup>	CO <sub>2</sub> , % <sup>d</sup>	CO, ppm <sup>e</sup>
1A	8/25	1131-1351	2574	740	553	43.7	10.0	8.2	338
1B	8/25	1609-1825	2687	798	527	43.4	10.0	8.2	277
2A	8/26	0718-0923	2635	792	553	41.2	9.4	7.8	19
2B	8/26	1054-1309	2749	790	565	43.2	9.4	7.8	29
3A	8/27	0726-1015	2836	834	560	41.7	8.0	9.4	21
3B	8/27	1150-1437	2717	797	555	42.2	8.8	8.0	14
4A	8/28	0740-1006	2998	852	580	43.2	7.1	9.7	16
4B	8/28	1143-1400	3136	944	565	40.7	9.4	7.0	<10

<sup>a</sup> Data were taken at Modified Method 5 sampling port.<sup>b</sup> Actual cubic feet per minute; flow rate at actual stack temperature and pressure.<sup>c</sup> Dry standard cubic feet per minute; standard conditions are 68°F, 29.92 in.Hg, and 0 percent moisture.<sup>d</sup> Dry basis.<sup>e</sup> Determined by CEM at secondary combustion chamber outlet.

TABLE 5-11. SUMMARY OF FLUE GAS CONDITIONS - METALS TRAIN<sup>a</sup>

Test Run No.	Date (1988)	Time (24-h)	Volumetric flow rate		Temperature, °F	Moisture content, %	Gas composition <sup>b</sup>			
			acfm <sup>c</sup>	dscfm <sup>d</sup>			O <sub>2</sub> % <sup>e</sup>	CO <sub>2</sub> % <sup>e</sup>	CO % <sup>e</sup>	ppm <sup>f</sup>
1A	8/25	1130-1350	2416	708	534	43.7	10.0	8.2		338
1B	8/25	1606-1806	2958	694	536	47.7	10.0	8.2		277
2A	8/26	0716-0922	2662	805	550	41.1	9.4	7.8		19
2B	8/26	1053-1208	2673	767	570	43.0	9.4	7.8		29
3A	8/27	0725-1030	2744	804	538	43.2	8.0	9.4		21
3B	8/27	1151-1450	2888	827	568	42.9	8.8	8.0		14
4A	8/28	0739-1006	2923	858	563	42.2	7.1	9.7		16
4B	8/28	1142-1400	3081	944	553	40.3	9.4	7.0		<10 <sup>9</sup>

<sup>a</sup> Data were taken at metals train sampling port.<sup>b</sup> Data were taken at MM5 sampling port.<sup>c</sup> Actual cubic feet per minute; flow rate at actual stack temperature and pressure.<sup>d</sup> Dry standard cubic feet per minute; standard conditions are 68°F, 29.92 in.Hg, and 0 percent moisture.<sup>e</sup> Dry basis.<sup>f</sup> Determined by CEM at secondary combustion chamber outlet.<sup>g</sup> Detection limit is 10 ppm.

An Orsat gas analyzer was used to measure gas composition ( $O_2$  and  $CO_2$ ) according to EPA Method 3 procedures.<sup>8</sup> An integrated bag sample was collected during each 2-hour test block. The  $O_2$  and  $CO_2$  values ranged between 7 and 10 percent throughout the test program. Reported CO values represent data collected by CEM at the secondary combustion chamber outlet.

### 5.3.2 Volatile and Semivolatile Organic Emissions Summary

Tables 5-12 and 5-13 summarize the volatile and semivolatile organic DRE data. Surrogate spiking compounds were added to the feed material just prior to incineration to evaluate the DRE for each compound class. A chlorobenzene spike was used to evaluate the volatile organic DRE, and 1,2-dichlorobenzene was used to evaluate the semivolatile organic DRE. The average total chlorobenzene feed rate was 8.67 lb/h, and the 1,2-dichlorobenzene feed rate was 13 lb/h. These feed rates, in conjunction with measured organic emission rates in pounds per hour, were used to calculate the DRE's for each test run.

As shown in Table 5-12, volatile organic mass rates were calculated with the average concentration [nanograms per liter (ng/liter)] determined for each test and the average volumetric flow from the MM5 train run simultaneously during each test period. Average chlorobenzene concentrations ranged between 3.5 and 12 ng/liter, and corresponding mass rates were between  $9.7 \times 10^{-6}$  and  $3.8 \times 10^{-5}$  lb/h. Greater than 99.999 percent DRE's were calculated for each test run, which indicates that chlorobenzene was effectively destroyed under each operating condition.

The semivolatile organics data summarized in Table 5-13 were measured by the MM5 sampling train. Concentrations and mass rates were calculated in accordance with standard EPA Method 5 procedures. Average concentrations ranged between  $7.7 \times 10^{-7}$  and  $1.0 \times 10^{-6}$  grains per dry standard cubic foot (gr/dscf), and corresponding mass rates were  $5.2 \times 10^{-6}$  and  $1 \times 10^{-5}$  lb/h, respectively. Greater than 99.999 percent DRE's were calculated for each test run, which indicates that 1,2-dichlorobenzene was effectively destroyed under each condition.

### 5.3.3 Particulate and HCl Emission Data

Tables 5-14 and 5-15 summarize the particulate and HCl emissions data, respectively. Concentrations are expressed in grains per dry standard cubic

TABLE 5-12. SUMMARY OF VOLATILE ORGANIC DRE DATA (CHLOROBENZENE)

Test Run No.	VOST Run No.	Concentration, ng/liter	Mass emission rate, lb/h	Analyte feed rate, lb/h	DRE, % <sup>a</sup>
1A	VO-1-1A	1.73	$4.7 \times 10^{-6}$	8.67	>99.999
	VO-1-1B	6.75	$18.3 \times 10^{-6}$		
	VO-1-1C	2.22	$6.0 \times 10^{-6}$		
	Average	3.57	$9.7 \times 10^{-6}$		
1B	VO-1-3A	0.424	$1.2 \times 10^{-6}$	8.67	>99.999
	VO-1-3B	6.93	$19.4 \times 10^{-6}$		
	VO-1-3D	12.6	$35.2 \times 10^{-6}$		
	Average	6.65	$18.6 \times 10^{-6}$		
2A	VO-2-1A	8.83	$26.4 \times 10^{-6}$	8.67	>99.999
	VO-2-1B	9.85	$29.5 \times 10^{-6}$		
	VO-2-1C	13.1	$39.1 \times 10^{-6}$		
	Average	10.6	$31.7 \times 10^{-6}$		
2B	VO-2-2A	8.53	$24.9 \times 10^{-6}$	8.67	>99.999
	VO-2-2B	7.18	$20.9 \times 10^{-6}$		
	VO-2-2C	4.78	$13.9 \times 10^{-6}$		
	Average	6.83	$19.9 \times 10^{-6}$		
3A	VO-3-1A	5.42	$16.6 \times 10^{-6}$	8.67	>99.999
	VO-3-1B	5.44	$16.7 \times 10^{-6}$		
	VO-3-1C	5.95	$18.3 \times 10^{-6}$		
	Average	5.60	$17.2 \times 10^{-6}$		
3B	VO-3-2A	5.16	$15.7 \times 10^{-6}$	8.67	>99.999
	VO-3-2B	4.98	$15.2 \times 10^{-6}$		
	VO-3-2C	7.68	$23.4 \times 10^{-6}$		
	Average	5.07	$15.4 \times 10^{-6}$		
4A	VO-4-1A	11.2	$35.8 \times 10^{-6}$	8.67	>99.999
	VO-4-1B	9.14	$29.3 \times 10^{-6}$		
	VO-4-1C	15.5	$49.7 \times 10^{-6}$		
	Average	11.9	$38.2 \times 10^{-6}$		
4B	VO-4-2A	10.6	$37.4 \times 10^{-6}$	8.67	>99.999
	VO-4-2B	10.4	$36.9 \times 10^{-6}$		
	VO-4-2C	10.6	$37.4 \times 10^{-6}$		
	Average	10.5	$37.2 \times 10^{-6}$		

$$^a \text{ DRE, \%} = \frac{(\text{lb/h in}) - \text{lb/h (out)}}{\text{lb/h (in)}} \times 100.$$

TABLE 5-13. SUMMARY OF SEMIVOLATILE ORGANIC DRE DATA (1,2-DICHLOROBENZENE)

Test Run No.	Concentration, gr/dscf <sup>a</sup>	Mass emission rate, lb/h	Analyte feed rate, lb/h	DRE, % <sup>b</sup>
1A	$2.32 \times 10^{-7}$	$1.47 \times 10^{-6}$	13.0	>99.999
1B	$1.31 \times 10^{-6}$	$8.94 \times 10^{-6}$	13.0	>99.999
Average	$7.71 \times 10^{-7}$	$5.21 \times 10^{-6}$	13.0	99.999
2A	$1.52 \times 10^{-6}$	$1.0 \times 10^{-5}$	13.0	>99.999
2B	$1.53 \times 10^{-6}$	$1.0 \times 10^{-5}$	13.0	>99.999
Average	$1.53 \times 10^{-6}$	$1.0 \times 10^{-5}$	13.0	>99.999
3A	$1.04 \times 10^{-6}$	$7.44 \times 10^{-6}$	13.0	>99.999
3B	$9.53 \times 10^{-7}$	$6.51 \times 10^{-6}$	13.0	>99.999
Average	$9.97 \times 10^{-7}$	$6.98 \times 10^{-6}$	13.0	>99.999
4A	$1.28 \times 10^{-6}$	$9.31 \times 10^{-6}$	13.0	>99.999
4B	$2.80 \times 10^{-7}$	$2.27 \times 10^{-6}$	13.0	>99.999
Average	$7.80 \times 10^{-7}$	$5.79 \times 10^{-6}$	13.0	>99.999

<sup>a</sup> Grains per dry standard cubic feet, standard conditions: 68°F, 29.92 in.Hg, and 0 percent moisture.

<sup>b</sup> DRE, % =  $\frac{(\text{lb/h in}) - \text{lb/h (out)}}{\text{lb/h (in)}} \times 100$ .

TABLE 5-14. SUMMARY OF PARTICULATE EMISSION DATA

Test Run No.	Concentration		Mass emission, rate	
	gr/dscf <sup>a</sup>	gr/dscf at 7% O <sub>2</sub>	lb/h	lb/100 dry feed
1A	1.11	1.41	7.04	3.61
1B	2.67	3.40	18.26	9.36
Average	1.89	2.40	12.65	6.48
2A	1.63	1.97	11.10	5.69
2B	0.72	0.87	4.88	2.50
Average	1.18	1.42	7.99	4.10
3A	0.39	0.43	2.82	1.45
3B	0.58	0.66	3.96	2.03
Average	0.48	0.54	3.39	1.74
4A	0.38	0.39	2.79	1.43
4B	0.30	0.36	2.45	1.26
Average	0.34	0.38	2.65	1.34

<sup>a</sup> Grains per dry standard cubic foot; standard conditions are 68°F, 29.92 in.Hg, and 0 percent moisture.

<sup>b</sup>  $\text{gr/dscf at 7 percent O}_2 = (\text{measured gr/dscf}) \left( \frac{21 - 7}{21 - \% \text{ O}_2} \right).$

TABLE 5-15. SUMMARY OF HCl EMISSIONS DATA

Test Run No.	Concentration, gr/dscf <sup>a</sup>	Mass emissions rate, lb/h	HCl emissions <sup>b</sup> , lb/h
1A	1.24	7.88	0
1B	3.14	21.49	11.49
Average	2.17	14.68	5.74
2A	1.91	12.95	2.95
2B	1.83	12.43	2.43
Average	1.87	12.69	2.69
3A	1.35	9.66	0
3B	1.94	13.27	3.27
Average	1.64	11.46	1.63
4A	5.36	39.14	29.14
4B	3.90	31.57	21.57
Average	4.63	35.36	23.36

<sup>a</sup> Grains per dry standard cubic foot; standard conditions are 68°F, 29.92 in.Hg, and 0 percent moisture.

<sup>b</sup> Corrected for contribution of spiking compounds. Approximately 10 lb/h of chlorine was added to the incinerator during the surrogate spiking of chlorobenzene and 1,2-dichlorobenzene.



foot, and mass rate data, in pounds per hour. The product of flue gas flow rate and concentration yields the mass rate in pounds per hour. Individual gas flow rates measured by the MM5 sampling train were used to calculate the mass rates.

The greatest particulate emissions occurred during lower temperatures in the kiln and secondary combustion chamber (Tests 1 and 2). Specifically, particulate concentrations ranged between 0.72 and 2.67 gr/dscf, with corresponding mass rates of 4.9 and 18.3 lb/h, respectively, during the four test runs conducted at the lower kiln temperature (1500°F). In comparison, particulate concentrations ranged between 0.30 and 0.60 gr/dscf, with corresponding mass rates of 2.5 and 4.0 lb/h, during the four test runs conducted at the higher kiln temperature (1800°F).

The average particulate mass rate during tests conducted at the lower temperature was 10.3 lb/h, compared with 2.9 lb/h for the high-temperature tests. The degree of variability in particulate data was higher during the lower-temperature tests (1 and 2). Variations of up to 11 lb/h were shown in Test 1, and variations of about 5 lb/h in Test 2. Variations of less than 1 lb/h were shown for Tests 3 and 4.

With regard to kiln residence time, an increase in particulate emissions was observed for the longer 60-minute residence time (Tests 1 and 3). The two-run average was 12.7 lb/h for Test 1 (60-minute residence), compared with 8 lb/h for Test 2 (30-minute residence), both of which were at the lower kiln temperature of 1500°F. The two-run average for Test 3 (60 minutes) was 3.4 lb/h, compared with 2.6 lb/h for Test 4 (30 minutes), both of which were measured at the higher kiln temperature of 1800°F.

Table 5-14 also summarizes the particulate mass emission rates in terms of lb/100 lb of dry feed. These results ranged from 1.26 to 9.36 lb/100 lb dry feed.

The HCl data summarized in Table 5-15 show emissions ranging from about 7.9 lb/h (Test Run 1A) to about 39 lb/h (Test Run 4A). The overall two-run averages for each test, excluding Test 4, were fairly consistent, ranging between 11.5 and 14.7 lb/h.

#### 5.3.4 Metals Emission Data

Table 5-16 summarizes the concentration and mass emission rate data for the metals analyzed during this test program. Concentrations are expressed

TABLE 5-16. SUMMARY OF METALS EMISSION DATA

Run No.	1A		1B		2A		2B	
Sample volume, dNm <sup>3</sup>	1.29		1.00		1.20		1.19	
Metal	ug/dNm <sup>3</sup>	lb/h	ug/dNm <sup>3</sup>	lb/h	ug/dNm <sup>3</sup>	lb/h	ug/dNm <sup>3</sup>	lb/h
Antimony	458	0.001	343	0.001	270	0.0008	107	0.0003
Arsenic	325	0.001	322	0.001	104	0.0003	54.5	0.0002
Barium	7,790	0.02	18,500	0.05	14,800	0.045	5,640	0.02
Beryllium	ND <sup>a</sup>	-	ND	-	ND	-	ND	-
Cadmium	10,600	0.03	7,330	0.02	4,520	0.01	7,900	0.023
Chromium	8,800	0.02	19,400	0.05	21,800	0.07	9,660	0.03
Copper	2,590	0.007	3,100	0.008	1,310	0.004	1,440	0.004
Lead	17,300	0.05	206,000	0.53	97,500	0.30	87,400	0.25
Mercury	1.7	0.0000045	2.7	0.0000070	1.3	0.0000040	2.1	0.000060
Nickel	513	0.001	1,030	0.003	720	0.002	465	0.001
Selenium	12.2	0.000032	8.8	0.000023	23.5	0.000071	20.7	0.000059
Silver	96.9	0.0003	43.6	0.0001	13.6	0.000041	37.6	0.0001
Vanadium	68.7	0.0002	152	0.0004	90.0	0.0003	44.6	0.12
Zinc	54,700	0.15	10,500	0.03	79,800	0.24	40,200	0.12

Run No.	3A		3B		4A		4B	
Sample volume, dNm <sup>3</sup>	1.31		0.832		0.912		0.973	
Metal	ug/dNm <sup>3</sup>	lb/h	ug/dNm <sup>3</sup>	lb/h	ug/dNm <sup>3</sup>	lb/h	ug/dNm <sup>3</sup>	lb/h
Antimony	648	0.002	927	0.003	567	0.002	524	0.002
Arsenic	550	0.002	481	0.002	296	0.001	305	0.001
Barium	876	0.003	1,540	0.005	780	0.003	460	0.002
Beryllium	ND	-	ND	-	ND	-	ND	-
Cadmium	5,150	0.02	5,220	0.02	5,590	0.02	6,640	0.02
Chromium	2,780	0.008	3,520	0.01	4,330	0.01	2,650	0.009
Copper	2,170	0.007	1,750	0.005	2,029	0.007	4,152	0.015
Lead	20,000	0.66	191,000	0.59	139,000	0.45	84,700	0.30
Mercury	1.5	0.0000046	5.6	0.000017	3.6	0.000012	3.3	0.000012
Nickel	1,410	0.004	701	0.002	2,630	0.008	1,900	0.007
Selenium	13.7	0.000040	29.2	0.000090	21.0	0.000066	5.9	0.000020
Silver	38.5	0.0001	20.8	0.000064	34.9	0.0001	49.5	0.0002
Vanadium	18.1	0.000039	24.8	0.000077	27.4	0.000088	205	0.000072
Zinc	82,500	0.25	117,000	0.36	80,400	0.26	9,000	0.21

<sup>a</sup> Nondetectable.

in micrograms per dry normal cubic meter ( $\mu\text{g}/\text{dNm}^3$ ) and mass emission rates, in pounds per hour. The volumetric flow rate measured by the metals train during each test period was used in the calculation of the mass emission rates. Lead and zinc showed the highest concentrations and mass rates of the listed metals. Lead mass rates ranged between 0.05 and 0.7 lb/h, and zinc mass rates ranged between 0.03 and 0.4 lb/h. Cadmium, chromium, and barium were also present at levels significantly above most of the other metals. Cadmium mass rates ranged between 0.01 and 0.03 lb/h, chromium mass rates ranged between 0.01 and 0.07 lb/h, and barium mass rates ranged between 0.002 and 0.05 lb/h. Table 5-17 presents the emission rate of the metals in the flue gas per 100 lb of dry feed. Lead mass rates ranged from 0.026 to 0.34 lb/100 lb dry feed, and zinc ranged from 0.015 to 0.18 lb/100 lb dry feed. In each case, the reported data represent total metals measured by the sample train, i.e., filterable plus condensible fractions. Both fractions were combined and digested prior to analysis, so there is no differentiation between filterable and condensible metals. Based on previous tests and analytical experience, the majority of these metals (arsenic, cadmium, and mercury are exceptions) would be expected to be in particulate form or combined with the particulates generated during incineration.

#### 5.3.5 Particulate Size Distribution

Table 5-18 and Figures 5-1 through 5-7 summarize the particle size distribution data for the seven samples collected during the incineration tests. Samples were collected at the completion of the MM5 and metals test runs, and sampling times ranged between 10 and 20 minutes.

Each individual impactor stage and the acetone rinse of the sampling nozzle and impactor casing were subjected to a gravimetric analysis. Cumulative size distribution data points representing the total weight of particulate matter smaller than the indicated aerodynamic particle diameter (in micrometers) were established for each test. The cut-points for each test were calculated by computer programs contained in "A Computer-Based Cascade Impactor Data Reduction System" (CIDRS) developed for the U.S. Environmental Protection Agency (EPA) by Southern Research Institute (SRI). All particle size results are based on a particle density of  $1 \text{ g}/\text{cm}^3$ . Data reduction for

TABLE 5-17. METALS EMISSIONS PER 100 POUNDS OF DRY FEED

Run No.	1A	1B	2A	2B	3A	3B	4A	4B
Metal								
Antimony	0.0005	0.0005	0.0004	0.00015	0.001	0.0015	0.001	0.001
Arsenic	0.0005	0.0005	0.00015	0.0001	0.001	0.001	0.0005	0.0005
Barium	0.01	0.0216	0.023	0.01	0.0015	0.0026	0.0015	0.001
Beryllium	-	-	-	-	-	-	-	-
Cadmium	0.015	0.01	0.005	0.012	0.01	0.01	0.01	0.01
Chromium	0.01	0.0216	0.0316	0.015	0.004	0.005	0.005	0.0046
Copper	0.0036	0.004	0.002	0.002	0.0036	0.0026	0.0036	0.0077
Lead	0.026	0.27	0.15	0.13	0.34	0.30	0.23	0.15
Mercury	0.0000023	0.0000036	0.0000020	0.000030	0.0000024	0.0000087	0.0000062	0.0000062
Nickel	0.0005	0.0015	0.001	0.005	0.002	0.001	0.004	0.0036
Selenium	0.000016	0.000012	0.000036	0.000030	0.000021	0.000046	0.000034	0.000010
Silver	0.00015	0.00005	0.000021	0.00005	0.00005	0.000033	0.00005	0.0001
Vanadium	0.0001	0.0002	0.00015	0.06	0.000020	0.000039	0.000045	0.000037
Zinc	0.077	0.015	0.12	0.06	0.13	0.18	0.13	0.11

TABLE 5-18. SUMMARY OF PARTICLE SIZE RESULTS

Test Run No.	Percent mass less than			
	1.0 $\mu\text{m}$	2.512 $\mu\text{m}$	10.00 $\mu\text{m}$	15.85 $\mu\text{m}$
1A	5.79	12.30	23.73	33.45
2A	6.26	10.46	17.53	34.26
2B	19.55	26.28	34.86	40.92
3A	48.14	54.78	61.52	66.12
3B	36.42	37.34	44.57	55.70
4A	24.44	27.06	31.32	37.04
4B	34.49	61.28	76.29	88.57

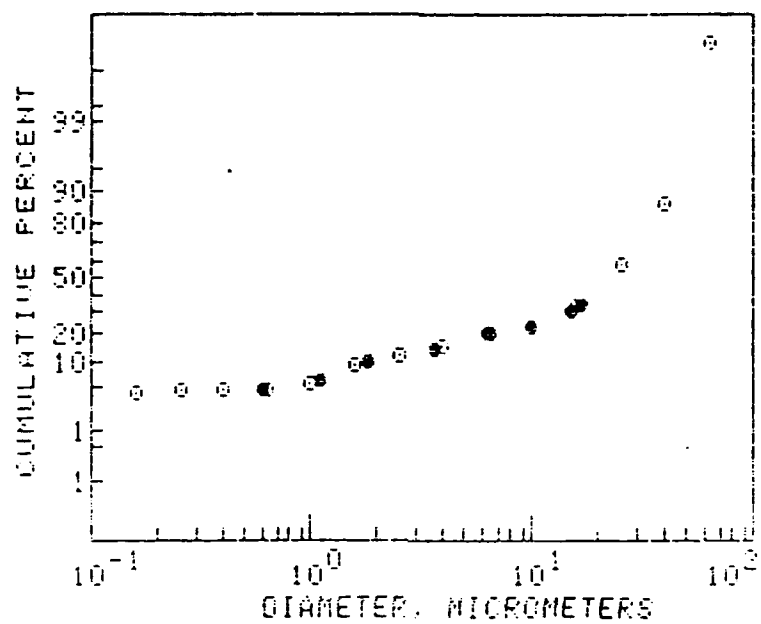


Figure 5-1. Particle size distribution (Test Run 1A).

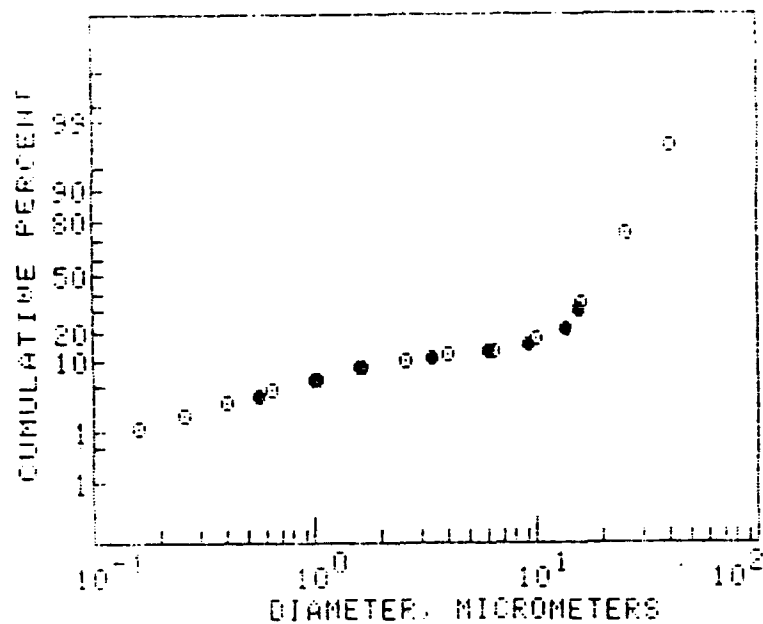


Figure 5-2. Particle size distribution (Test Run 2A).

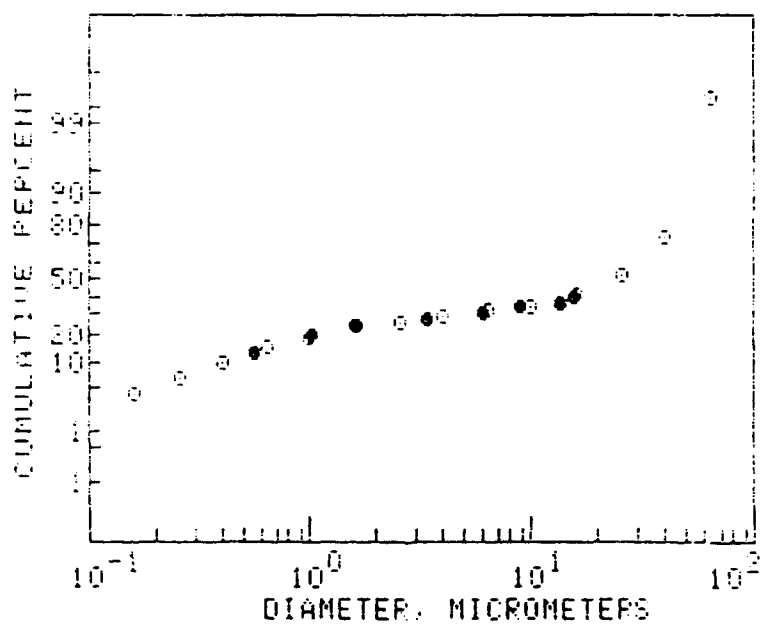


Figure 5-3. Particle size distribution (Test Run 2B).

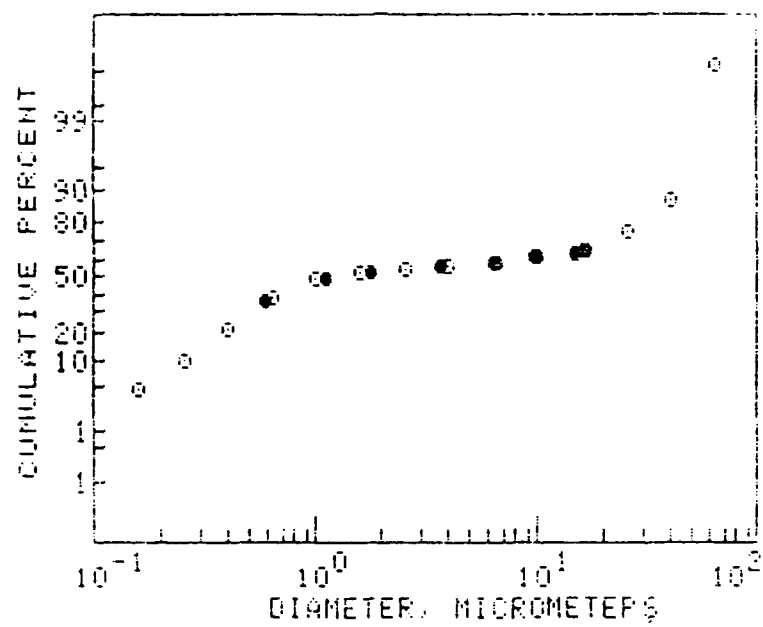


Figure 5-4. Particle size distribution (Test Run 3A).

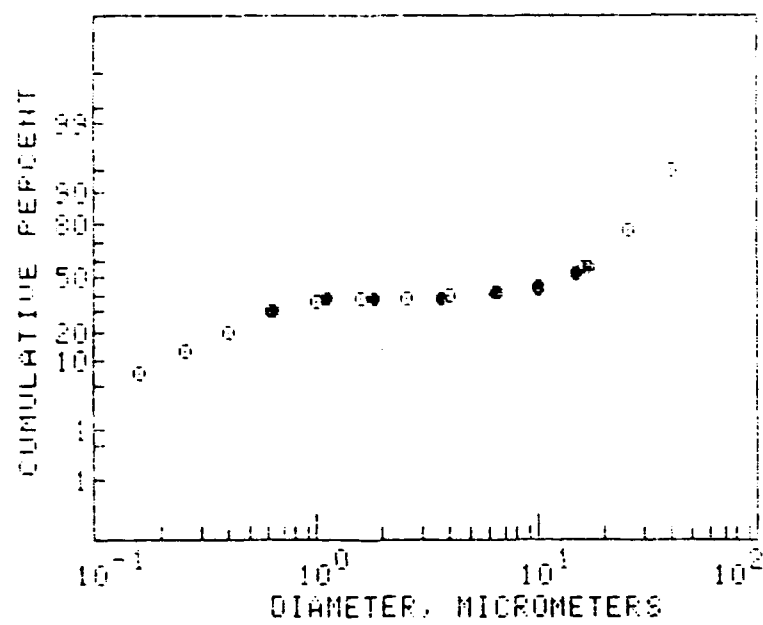


Figure 5-5. Particle size distribution (Test Run 3B).



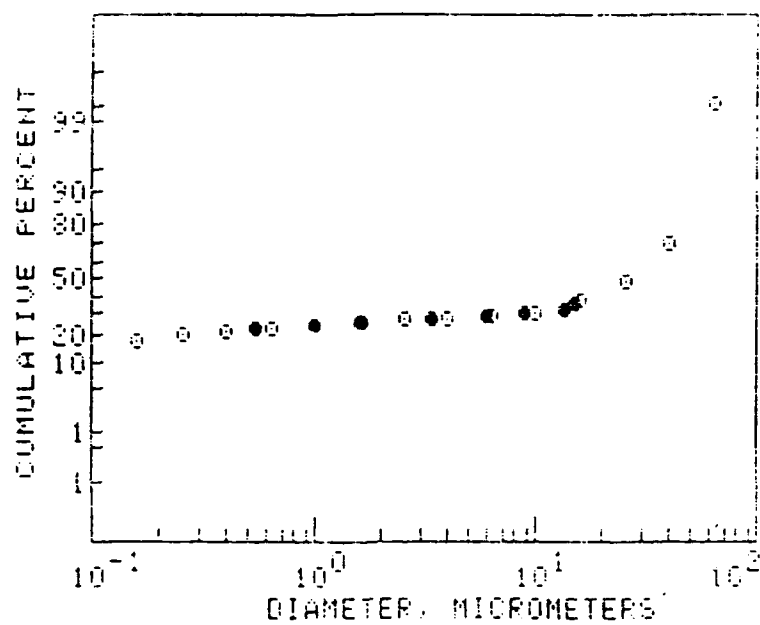


Figure 5-6. Particle size distribution (Test Run 4A).

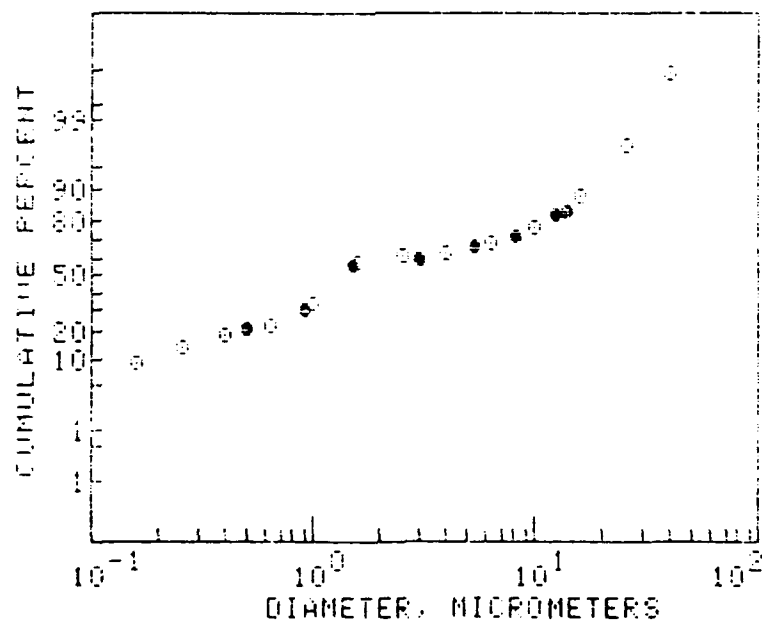


Figure 5-7. Particle size distribution (Test Run 4B).

the particle size tests was performed by computer programming; data on flue gas moisture and molecular weight were obtained from the particulate tests run prior to the particle size tests.

The average isokinetic sampling rates were all within the acceptable range of 80 to 120 percent, and the impactor sampling rates were all within the manufacturer's suggested operating limits (0.3 to 0.75 acfm).

The results of the three runs conducted at the lower kiln temperature (1A, 2A, and 2B) show between 6 and 20 percent of the particles to be less than 1.0  $\mu\text{m}$  in diameter; between 18 and 35 percent, less than 10  $\mu\text{m}$  in diameter; and 33 to 41 percent, less than 15  $\mu\text{m}$  in diameter. Therefore, the majority of particles are larger than 15  $\mu\text{m}$  at the lower kiln temperature. In contrast, the results for the four runs conducted at the higher temperature (3A, 3B, 4A, and 4B) show between 24 and 48 percent of the particles to be less than 1.0  $\mu\text{m}$  in diameter; between 27 and 61 percent, less than 10  $\mu\text{m}$  in diameter; and between 37 and 88 percent, less than 15  $\mu\text{m}$  in diameter. Upon field recovery, samples from Test Run 4B were found to be contaminated with an oily substance, particularly in the lower impactor stages. The source of this contamination is unknown. This would tend to bias results on the low side and make data from this run questionable. Nevertheless, the percentage of particles with diameters less than 25 and 10  $\mu\text{m}$  increases with increasing kiln temperature.

### 5.3.6 Continuous Emission Monitoring Data and Secondary Combustion Chamber Temperature Data

The gas composition data continuously recorded at the sampling locations of the secondary combustion chamber outlet and the conditioning tower outlet are summarized in Tables 5-19 through 5-26. These tables also include temperature data continuously recorded at the secondary combustion chamber outlet. All data were reduced by using 10-minute averages. Short interruptions in data recordings were necessary to clean out the filtering and conditioning systems. When an interruption occurred, the data were appropriately marked and the continuous monitors restarted as soon as possible. Temperature,  $\text{CO}_2$ ,  $\text{O}_2$ , and CO were all monitored at the secondary combustion chamber outlet. Both  $\text{SO}_2$  and  $\text{NO}_x$  were monitored at the conditioning tower outlet.

Test Runs 1A, 1B, 2A, and 2B had secondary combustion chamber temperatures ranging from 1527° to 1725°F. The average temperature during these

TABLE 5-19. SUMMARY OF CEM AND SECONDARY COMBUSTION CHAMBER TEMPERATURE DATA  
AUGUST 25, 1988, RUN 1A

Time (24-h)	Interval, minutes	Secondary combustion chamber outlet				Conditioning tower outlet			
		Concentration, %		CO concentration, ppm		Concentration, ppm		Concentration, ppm	
		CO <sub>2</sub>	O <sub>2</sub>	Average	Maximum	Temperature, °F	NO <sub>x</sub>	NO	SO <sub>2</sub>
1120-1130	10	9.8	7.7	648.0	1000 <sup>a</sup>	1641	86.4	-	2 (<10) <sup>e</sup>
1130-1140	10	9.0	8.5	202.0	-	1627	- <sup>b</sup>	- <sup>b</sup>	0 (<10)
1140-1150	10	9.8	7.9	328.3	-	1685	66.4	-	4.7 (<10)
1150-1200	10	10.2	7.2	647.7	1000+	1650	-	26.6	14.0
1200-1210	10	10.3	7.1	483.3	1000+	1762	-	26.6	14.0
1210-1220	10	- <sup>c</sup>	- <sup>c</sup>	- <sup>c</sup>	- <sup>c</sup>	1725	78.4	-	23.9
1220-1230	10	12.4	3.3	500.0	1000+	1675	-	18.3	47.4
1230-1240	10	13.3	3.1	250.0	-	1653	34.5	-	26.6
1240-1250	10	12.1	4.8	48.0	-	1627	-	16.6 <sup>d</sup>	15.7
1250-1300	10	10.9	5.7	101.2	-	1615	17.3	-	10.2
1300-1310	10	11.9	4.5	159.6	-	1609	-	8.6 <sup>d</sup>	7.4 (<10)
1310-1320	10	11.6	5.3	186.1	-	1617	12.2	-	7.4 (<10)
1320-1330	10	11.7	5.4	286.9	-	1600	-	6.6 <sup>d</sup>	7.4 (<10)
1330-1340	10	12.0	3.6	271.0	-	1630	11.4	-	7.4 (<10)
1340-1350	10	13.2	3.5	430.2	-	1655	-	6.6 <sup>d</sup>	12.9
1350-1400	10	13.3	3.0	531.0	-	1651	11.3	-	15.7
Average		11.4	5.4	338.2	-	1645	66.4	23.8	13.5

<sup>a</sup> Off scale on the 0 to 1000 ppm scale.

<sup>b</sup> Clogged capillary prevented sample flow to instrument.

<sup>c</sup> Flow restricted, filter was changed.

<sup>d</sup> Capillary tubes plugged - results biased low - not included in average.

<sup>e</sup> Results based on extrapolating.

TABLE 5-20. SUMMARY OF CEM AND SECONDARY COMBUSTION CHAMBER TEMPERATURE DATA  
AUGUST 25, 1988, RUN 1B

Time (24-h)	Interval, minutes	Secondary combustion chamber outlet					Conditioning tower outlet			
		Concentration, %		CO con- centration, ppm		Tempera- ture, °F	Concentration, ppm			Concen- tration, ppm SO <sub>2</sub>
		CO <sub>2</sub>	O <sub>2</sub>	Average	Maximum		NO <sub>x</sub>	NO		
1600-1610	10	-	-	-	-	1600	-	-	-	-
1610-1620	10	11.0	7.5	111.8	-	1585	-	44.8	29.2	29.2
1620-1630	10	9.9	7.6	194.1	-	1600	-	43.3	21.5	21.5
1630-1640	10	9.6	4.8	327.8	976	1700	160.7	-	41.1	41.1
1640-1650	10	11.2	6.2	1000	-	1600	-	30.1	38.2	38.2
1650-1700	10	10.5	7.7	209.5	-	1600	<sup>a</sup>	-	26.2	26.2
1700-1710	10	10.1	8.1	255.8	-	1585	<sup>a</sup>	-	20.3	20.3
1710-1720	10	9.7	7.1	142.6	-	1600	<sup>a</sup>	-	32.2	32.2
1720-1730	10	9.5	7.5	471.8	-	1585	125.5	-	21.5	21.5
1730-1740	10	10.2	7.6	348.4	-	1588	-	40.4	17.3	17.3
1740-1750	10	9.9	7.1	204.4	-	1623	74.1	-	17.3	17.3
1750-1800	10	10.1	6.0	116.9	-	1645	-	38.9	20.3	20.3
1800-1810	10	10.9	6.8	173.5	-	1628	71.2	-	20.3	20.3
1810-1820	10	10.5	7.7	50.0	-	1614	-	46.3	14.3	14.3
Average		10.2	7.1	277.4	-	1611	107.9	40.6	24.6	24.6

<sup>a</sup> Clogged capillary prevented sample flow to instrument.

TABLE 5-21. SUMMARY OF CEM AND SECONDARY COMBUSTION CHAMBER TEMPERATURE DATA  
AUGUST 26, 1988, RUN 2A

Time (24-h)	Interval, minutes	Secondary combustion chamber outlet				Conditioning tower outlet			
		Concentration, %		CO con- centration, ppm		Concentration, ppm		Concen- tration, ppm SO <sub>2</sub>	
		CO <sub>2</sub>	O <sub>2</sub>	Average	Maximum	Temperature, °F	NO <sub>x</sub>	NO	
0715-0725	10	-	-	-	-	1575	-	-	-
0725-0735	10	11.1	5.9	22.9	-	1582	61.5	-	18.3
0735-0745	10	11.0	6.2	16.7	-	1585	-	60.1	17.7
0745-0755	10	10.8	6.3	15.6	-	1571	65.7	-	16.5
0755-0805	10	9.9	7.3	16.1	-	1573	-	82.6	19.5
0805-0815	10	10.6	6.3	20.1	-	1574	68.5	-	21.3
0815-0825	10	10.6	6.1	26.8	-	1574	67.1	-	22.5
0825-0835	10	10.0	7.0	25.7	-	1566	-	61.0	16.5
0835-0845	10	8.6	8.1	15.0	530 <sup>a</sup>	1575	91	-	10.5
0845-0855	10	8.9	5.6	17.3	-	1580	85.4	-	11.7
0855-0905	10	10.6	5.9	17.3	-	1588	-	51.7	15.3
0905-0915	10	12.1	3.0	18.4	-	1593	64.3	-	25.5
0915-0925	10	11.6	4.6	20.1	-	1599	-	48.1	24.3
Average		10.5	6.0	19.3	-	1580	71.9	60.7	18.3

<sup>a</sup> Off scale on the 0 to 500 ppm scale.

TABLE 5-22. SUMMARY OF CEM AND SECONDARY COMBUSTION CHAMBER TEMPERATURE DATA  
AUGUST 26, 1988, RUN 2E

		Secondary combustion chamber outlet				Conditioning tower outlet		
Time (24-h)	Interval, minutes	Concentration, %		CO con- centration, ppm	Tempera- ture, °F	Concentration, ppm		Concen- tration, ppm SO <sub>2</sub>
		CO <sub>2</sub>	O <sub>2</sub>			NO <sub>x</sub>	NO	
1045-1055	10	-	-	-	1527	-	-	-
1055-1105	10	11.2	6.5	18.5	1539	-	50.2	1.2 (<10) <sup>a</sup>
1105-1115	10	10.7	6.0	21.9	1537	52.1	-	1.0 (<10)
1115-1125	10	11.8	4.8	34.5	1542	-	43.2	3.0 (<10)
1125-1135	10	12.2	4.8	37.9	1538	51.6	-	4.2 (<10)
1135-1145	10	12.0	4.8	45.9	1531	-	41.8	5.4 (<10)
1145-1155	10	11.7	5.7	45.9	1519	58.0	-	4.2 (<10)
1155-1205	10	11.2	6.0	35.6	1538	-	50.2	2.4 (<10)
1205-1215	10	11.4	6.0	29.9	1549	71.2	-	1.2 (<10)
1215-1225	10	11.0	6.8	29.9	1541	-	74	1.0 (<10)
1225-1235	10	10.5	6.7	24.2	1543	82.4	-	2.4 (<10)
1235-1245	10	10.2	7.2	19.0	1548	-	114.6	0.0 (<10)
1245-1255	10	9.8	7.3	17.3	1543	110.4	-	0.0 (<10)
1255-1305	10	10.1	7.2	20.2	1551	-	113.2	0.0 (<10)
Average		11.1	6.1	29.3	1539	71.0	9.6	2.0 (<10)

<sup>a</sup> Detection limit is 10 ppm. Values given are estimates based on extrapolating.

TABLE 5-23. SUMMARY OF CEM AND SECONDARY COMBUSTION CHAMBER TEMPERATURE DATA  
AUGUST 27, 1988, RUN 3A

Time (24-h)	Interval, minutes	Secondary combustion chamber outlet			Conditioning tower outlet		
		Concentration, %		Tempera- ture, °F	Concentration, ppm		Concen- tration, ppm SO <sub>2</sub>
		CO <sub>2</sub>	O <sub>2</sub>		NO <sub>x</sub>	NO	
0720-0730	10	-	-	1935	-	-	-
0730-0740	10	6.2	12.3	1951	-	153.2	23.4
0740-0750	10	6.5	11.8	1965	129.5	-	24.6
0750-0800	10	7.1	11.0	1970	-	-	26.6
0700-0810	10	6.6	12.3	1965	139.6	-	22.7
0810-0820	10	6.7	11.5	1964	-	141.3	22.1
0820-0830	10	7.3	10.9	1972	134.6	-	19.5
0830-0840	10	7.3	11.2	1969	-	131.2	22.1
0840-0850	10	6.7	12.2	1984	161.6	-	22.1
0850-0900	10	7.5	11.2	1974	-	158.3	22.7
0900-0910	10	8.5	9.3	1970	114.3	-	41.3
0910-0920	10	6.2	12.6	1929	-	188.7	27.8
0920-0930	10	6.1	12.6	1938	205.6	-	23.4
0930-0940	10	6.2	12.4	1940	-	195.5	24.0
0940-0950	10	6.4	12.2	1947	178.6	-	24.0
0950-0100	10	6.0	12.5	1942	-	195.5	22.3
Average		6.8	11.7	1957	152.0	166.2	24.6

TABLE 5-24. SUMMARY OF CEM AND SECONDARY COMBUSTION CHAMBER TEMPERATURE DATA  
AUGUST 27, 1988, RUN 38

Time (24-h)	Interval, minutes	Secondary combustion chamber outlet			Conditioning tower outlet		
		Concentration, %		CO con- centration, ppm	Concentration, ppm		Concen- tration, ppm SO <sub>2</sub>
		CO <sub>2</sub>	O <sub>2</sub>		NO <sub>x</sub>	NO	
1145-1155	10	11.4	5.3	11.9	-	131.6	21.4
1155-1205	10	13.1	3.7	15.8	-	152.0	27.3
1205-1215	10	12.9	4.4	16.9	154.9	-	33.2
1215-1225	10	12.1	4.4	16.9	-	154.9	30.3
1225-1235	10	11.1	6.1	15.8	157.8	-	29.1
1235-1245	10	10.9	6.1	14.7	-	146.2	23.1
1245-1255	10	12.0	4.5	14.7	166.5	-	20.8
1255-1305	10	11.6	4.8	14.7	-	160.7	26.1
1305-1315	10	11.9	4.3	13.0	163.6	-	26.1
1315-1325	10	12.2	4.2	14.7	-	162.1	29.7
1325-1335	10	11.1	6.1	13.0	146.2	-	17.2
1335-1345	10	11.2	6.1	13.0	-	152.0	15.4
1345-1355	10	11.2	6.0	13.0	149.1	-	13.7
1355-1405	10	11.0	6.2	13.0	-	146.2	13.7
Average		11.7	5.1	14.4	156.4	150.7	23.4



TABLE 5-25. SUMMARY OF CEM AND SECONDARY COMBUSTION CHAMBER TEMPERATURE DATA  
AUGUST 28, 1968, RUN 4A

Time (24-h)	Interval, minutes	Secondary combustion chamber outlet				Conditioning tower outlet			
		Concentration, %		CO con- centration, ppm	Tempera- ture, °F	Concentration, ppm		Concen- tration, ppm SO <sub>2</sub>	
		CO <sub>2</sub>	O <sub>2</sub>			NO <sub>x</sub>	NO		
0730-0740	10	11.6	4.4	16.8	1961	-	121.6	-	18.6
0740-0750	10	11.9	4.2	17.9	1954	-	124.4	-	16.8
0750-0800	10	12.5	3.6	17.3	1960	133.0	-	-	18.0
0700-0810	10	12.2	4.0	16.8	1963	-	140.2	-	16.8
0810-0820	10	11.1	4.9	16.2	1960	130.2	-	-	16.8
0820-0830	10	11.4	5.0	16.2	1959	-	127.3	-	18.6
0830-0840	10	11.0	4.9	15.0	1965	131.6	-	-	18.0
0840-0850	10	11.4	4.4	15.0	1970	-	128.7	-	18.6
0850-0900	10	11.9	3.9	15.6	1985	133.0	-	-	20.5
0900-0910	10	11.9	3.7	16.2	1974	-	128.7	-	22.9
0910-0920	10	12.5	3.2	16.2	1978	113.0	-	-	26.6
0920-0930	10	12.4	4.3	16.2	1965	-	111.5	-	22.9
0930-0940	10	12.0	3.9	15.6	1980	107.2	-	-	26.0
0940-0950	10	11.1	5.7	14.4	1968	-	135.9	-	22.9
0950-0100	10	11.5	5.0	15.0	1976	133.0	-	-	19.9
Average		11.8	4.3	16.0	1968	125.9	127.3	-	20.3

TABLE 5-26. SUMMARY OF CEM AND SECONDARY COMBUSTION CHAMBER TEMPERATURE DATA  
AUGUST 28, 1988, RUN 4R

Time (24-h)	Interval, minutes	Secondary combustion chamber outlet				Conditioning tower outlet			
		Concentration, %		CO con- centration, ppm	Tempera- ture, °F	Concentration, ppm		Concen- tration, ppm SO <sub>2</sub>	
		CO <sub>2</sub>	O <sub>2</sub>			NO <sub>x</sub>	NO		
1130-1140	10	12.0	4.8	6.9 (<10) <sup>a</sup>	1974	133.4	-	10.6	
1140-1150	10	11.8	5.0	6.9 (<10)	1981	136.2	-	7.6 (<10) <sup>a</sup>	
1150-1200	10	11.5	5.5	6.9 (<10)	1977	-	134.8	7.1 (<10)	
1200-1210	10	11.5	5.5	8.7 (<10)	1976	136.2	-	6.5 (<10)	
1210-1220	10	12.0	4.1	8.1 (<10)	1979	-	132.0	9.4 (<10)	
1220-1230	10	11.8	5.3	8.7 (<10)	1986	144.5	-	8.8 (<10)	
1230-1240	10	11.5	5.4	8.7 (<10)	1985	-	150.1	7.6 (<10)	
1240-1250	10	11.6	5.4	8.7 (<10)	1984	147.3	-	9.4 (<10)	
1250-1300	10	11.5	5.3	9.2 (<10)	1987	-	150.1	9.4 (<10)	
1300-1310	10	12.0	4.7	9.8 (<10)	1995	120.8	-	7.6 (<10)	
1310-1320	10	12.0	5.3	9.8 (<10)	1991	-	151.5	11.2	
1320-1330	10	10.2	6.0	8.7 (<10)	1983	144.5	-	7.2 (<10)	
1330-1340	10	10.2	6.4	9.8 (<10)	1978	-	145.9	4.7 (<10)	
1340-1350	10	9.8	6.5	10.4	1974	151.5	-	5.3 (<10)	
Average		11.4	5.4	8.7 (<10)	1982	139.3	144.1	8.0 (<10)	

<sup>a</sup> Detection limit is 10 ppm. Values given are estimates based on extrapolating.

four runs was 1594°F. The CO<sub>2</sub> concentration ranged from 9 to 13.3 percent and averaged 10.8 percent during the four runs. The O<sub>2</sub> concentration ranged from 3 to 8.5 percent and averaged 6.2 percent during the four runs. The CO concentration ranged from 16 to 1000+ ppm (offscale on 0-to-1000 scale). Runs 1A and 1B had an average CO concentration of 308 ppm, and several spikes greater than 1000 ppm occurred. Runs 2A and 2B were very stable; the average CO concentration was 24.3 ppm, which corresponded with maximum readings of less than 50 ppm.

Test Runs 3A, 3B, 4A, and 4B showed temperatures ranging from 1929° to 1995°F at the secondary combustion chamber outlet. The average temperature for all four runs was 1968°F. The CO<sub>2</sub> concentrations ranged from 6.0 to 13.1 percent and averaged 10.4 percent. Run 3A had a much lower average CO<sub>2</sub> concentration (6.8 percent) compared with Runs 3B, 4A, and 4B (11.6 percent). The O<sub>2</sub> concentrations ranged from 3.2 to 12.6 percent and averaged 6.6 percent. Run 3A had a much higher average O<sub>2</sub> concentration (11.7 percent) than did Runs 3B, 4A, and 4B (4.9 percent). The CO concentration ranged from 6.9 to 74.7 ppm and averaged 14.9 ppm for all four runs. The CO values were very consistent during this portion of the program.

Continuous monitoring for concentrations of SO<sub>2</sub> and NO<sub>x</sub> at the conditioning tower took place simultaneously with CO, O<sub>2</sub>, and CO<sub>2</sub> testing at the secondary combustion chamber outlet. Total NO<sub>x</sub> values are reported. The NO<sub>x</sub> and nitric oxide (NO) values were very similar for all test runs, indicating that the primary form of NO<sub>x</sub> is nitric oxide (NO). The NO<sub>x</sub> portion of the gas stream consists primarily of NO and nitrogen dioxide (NO<sub>2</sub>); i.e., NO + NO<sub>2</sub> = total NO<sub>x</sub>. The NO<sub>2</sub> fraction can be estimated from the difference between total NO<sub>x</sub> and NO. During the low-temperature runs (1A, 1B, 2A, and 2B), NO<sub>x</sub> concentrations ranged from 11.3 to 160.7 ppm and averaged 79.3 ppm for the four runs. The SO<sub>2</sub> concentrations ranged from nondetectable (less than 10 ppm) to 47.4 ppm and averaged 14.6 ppm for the four test runs.

During the high-temperature runs (3A, 3B, 4A, and 4B), NO<sub>x</sub> concentrations ranged from 107 to 205 ppm and averaged 143 ppm for the four runs. As expected, NO<sub>x</sub> concentrations increased with increasing kiln temperature. The SO<sub>2</sub> concentrations ranged from 4.7 to 41 ppm and averaged 19 ppm for the four test runs. The NO<sub>x</sub> and SO<sub>2</sub> data were consistent during each test run.

#### 5.4 OPERATIONAL DATA

Appendix A presents the operational data as collected during the full test program. Table 5-27 summarizes the average values for each test.

TABLE 5-27. SUMMARY OF AVERAGE OPERATIONAL DATA

Parameter	Test Number			
	1	2	3	4
Kiln				
Fuel rate, mm Btu/h	0.611	0.657	0.634	0.707
Operating temperature, °F	1597	1499	1803	1804
Oxygen in flue gas, %	12.36	7.15	6.45	7.78
Combustion air rate, scfm	252	316	423	366
Secondary combustion chamber				
Fuel rate, mm Btu/h	0.658	0.664	1.022	1.279
Temperature, °F	1612	1615	1998	1998
Oxygen flue gas, %	6.17	6.07	5.81	5.2
Combustion air rate, scfm	183	111	123	200

## SECTION 6

### EVALUATION

#### 6.1 FEED CHARACTERIZATION

The spent PBM and agricultural blast media-walnut shells (ABM) that were tested contained a wide range of metal concentrations. The low, high, and average values of the metal concentrations in the feed samples (dry basis), as well as the standard deviation and relative standard deviation of each are presented in Table 6-1. The variability of metals in the shot blast residue reflects the fact that the metal content of spent blast media was determined by many factors, including the metal content of the pigments in the paint removed, how readily the paint was removed (paints that are difficult to remove require more blast media and thus result in lower metal concentrations because of dilution), and the efficiency of the blasting operation on different kinds of parts. The metals content of the familiarization samples taken near the beginning of the project were biased low (Table 2-2) compared with the tested waste. As was shown in Table 5-3, the average metal contents of the ABM and PBM in the familiarization samples were lower than the lowest metal concentrations in the tested material (on a dry basis), except for barium.

The relatively high Btu value of the mixed waste on a dry basis (Table 5-1) is an advantage in incineration. During the low-temperature tests, the rotary-kiln temperature could not be maintained at 1400°F as originally planned because the heating value of the mixed waste--even after the addition of water--was too high. This waste did not require an excessive input of energy to burn, however, and mixing the waste with other types of paint waste with low Btu values could be feasible. In fact, mixing the dry ABM and PBM with another material (water was used during the test program) was necessary to prevent the blast media from blowing through the kiln.

TABLE 6-1. CONCENTRATIONS OF METALS IN FEED (DRY BASIS)  
[ug/g (ppm)]

Total metals, ug/g (ppm)	Low value	High value	Average	Standard deviation	Relative standard deviation <sup>a</sup>
Arsenic	1.6	11.4	3.8	3.2	84
Barium	22.6	733	504	188	37
Cadmium	76.8	150	106	236	22
Chromium	595	2340	1470	1627	42
Lead	1800	8320	5070	2440	48
Mercury	ND <sup>b</sup>	ND	ND	—	—
Selenium	<0.12 <sup>c</sup>	2.7	1.1	0.84	76
Silver	1.3	30.6	7.4	9.8	132

<sup>a</sup> Relative Standard Deviation = Standard deviation ÷ average x 100%

<sup>b</sup> Mercury was not detected in any feed samples.

<sup>c</sup> < Indicates concentration of metal was below the specified detection limit

As expected, only a few organics were found in the spent shot blast and these (methylene chloride, acetone, 4-methyl-2-pentanone, methanol, 2-methylphenol, 4-methylphenol, and 1,2-dichlorobenzene) were present in low-ppm ranges. Traces of several of these organics, including methylene chloride, acetone, and methanol, could represent analytical artifacts. The tested organics are a minor constituent of shot blast residue.

## 6.2 ASH

A total volume of 1155 gallons (twenty-one 55-gallon drums) of blast residue was incinerated, and less than one-third of a drum (~15 gallon volume) of kiln ash was generated. Even if the ash were hazardous, it would present only a minimal disposal problem compared with the original volume.

Small quantities of methylene chloride and acetone were the only organics quantified in the incinerator ash. These compounds are common laboratory artifacts. Tested organics, other than surrogate spiking compounds, were not detected in the ash. Methylene chloride concentrations ranged from 130 to 5400 ppb and exceeded 500 ppb in only the ash generated during Test 2. Acetone ranged from 140 to 6400 ppb with the highest concentrations present in ash from Test 2. The volatile organic surrogate spiking compound, chlorobenzene, was present in low concentrations (190 ppb) of ash generated during Test Runs 1B and 3B (39 ppb); it was also detected in the ash from Test Run 4A (8 ppb). The semivolatile surrogate spiking compound, 1,2-dichlorobenzene, was present at 710 ppb in the ash of Test Run 1A and was below the detection level in other ash samples.

Table 6-2 presents the ratio of the concentrations of metals present in the ash to the concentration of metals present in untreated blast residue. This ratio, in effect, normalizes the data to account for variations in the metal concentrations in the incinerator feed during each run. Arsenic, barium, and silver concentrations increased in the kiln ash compared with those in the feed, whereas the other metal concentrations decreased. Figure 6-1 shows the ratio of concentrations in ash to feed for those metals that were enriched in the ash (i.e., the ratio is greater than 1), and Figure 6-2 shows the same ratio for those metals that were not enriched in the ash

TABLE 6-2. RATIO OF METAL CONCENTRATIONS IN KILN ASH TO METAL CONCENTRATIONS IN FEED

Metal	Test Run Number									
	1A	1B	Test 1 Average	2A	2B	Test 2 Average	3R	4A	4B	Test 4 Average
Arsenic	7.4	4.6	6.0	6.3	15.8	11.1	4.3	3.4	0.060	1.7
Barium	2.8	4.0	3.4	4.0	3.2	3.6	2.0	1.5	0.93	1.2
Cadmium	0.047	0.045	0.046	0.10	0.05	0.075	0.059	0.025	0.008	0.016
Chromium	0.41	0.55	0.48	0.59	0.67	0.63	0.24	0.16	0.090	0.25
Lead	0.17	0.22	0.195	0.66	0.58	0.62	0.087	0.065	0.026	0.046
Mercury	ND <sup>a</sup>	ND	ND	ND	ND	ND	ND	ND	ND	ND
Selenium	0 <sup>b</sup>	ND	0	0	0.47	0.235	0	0	ND	0
Silver	9.2	4.9	7.0	18.3	16.8	17.6	2.7	0.050	0	0.025

<sup>a</sup> Metal was not detected in feed or ash.

<sup>b</sup> Metal was detected in feed but not in ash.



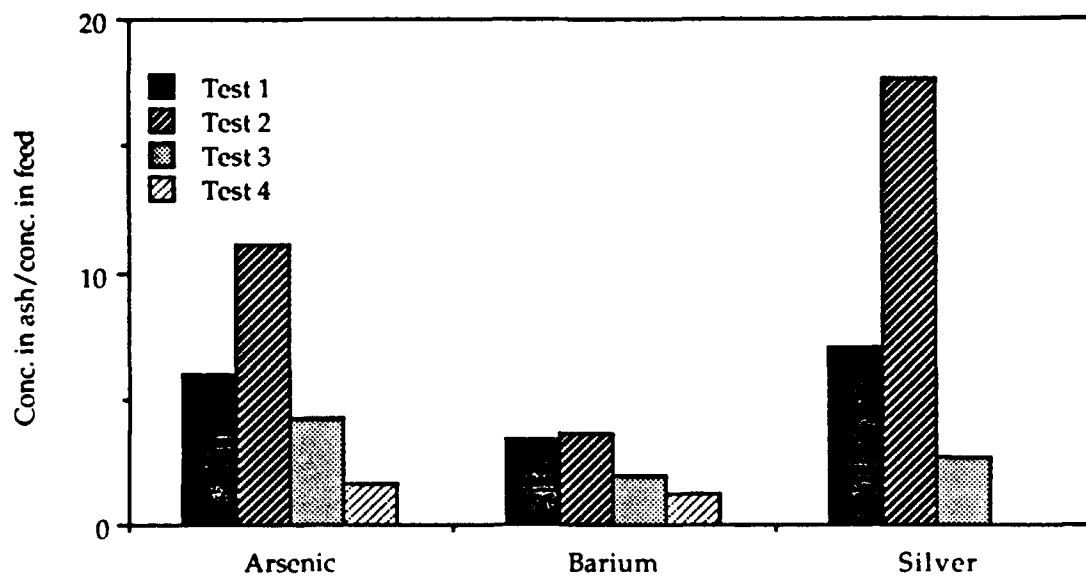


Figure 6-1. Concentration of metals enriched in ash relative to feed.

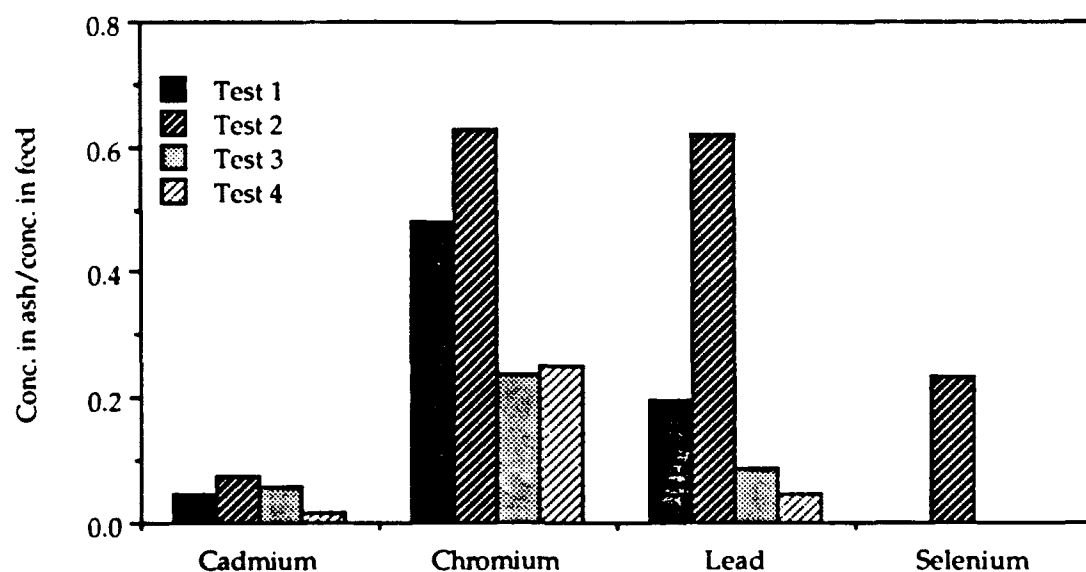


Figure 6-2. Concentration of metals not enriched in ash relative to feed.

(ratio is less than 1). These graphs were prepared with the two-run average for each test. For both sets of metals, the following trends appear:

- ° At the lower kiln temperature, the ratios decrease with increasing residence times; i.e., the metals do not have enough time to volatilize in the shorter residence time.
- ° At the higher kiln temperature, the ratio generally increases with increasing residence time.
- ° At either residence time, the higher kiln temperature decreases the amount of metals in the ash compared with metals in the feed. As expected, more metals are volatilized at a higher temperature.

Only Test Run 3B produced an ash that failed the TCLP test for any of the metals. (Run 3A did not produce enough ash to analyze.) This ash, however, did not show a greater total concentration of metals than in the other test; in fact, the metal concentration in the ash during Test 3B was less than that in the ash during Tests 1 and 2, and greater than that during Test 4. This reflects the previously noted fact that higher temperatures volatilize more metals and thus generate a kiln ash with a lower metal content.

Focusing only on the ash metal content does not account for the variability in the feed. Table 6-3 presents the ratio of metal concentrations in TCLP extracts to the metal concentrations in ash during each test run. As in Table 6-1, this ratio normalizes the data to account for the variations in ash concentrations so that the results of the TCLP are given in relation to the ash characteristics. Figures 6-3 and 6-4 show the averages for each test graphically. The TCLP extraction involves a liquid/solid ratio of 20 to 1; therefore, if all the metals were leached out of the solid ash, the TCLP/ash ratio would be 0.05. Thus, the upper limit for Figure 6-4 is 0.05. Based on the information presented in the tables and diagrams, the TCLP/ash metal concentration appears to be higher at higher temperatures, which indicates that the metals are in a more leachable form than they are at the lower temperatures. Previous reports concluded that temperatures greater than 2000°F decomposed barium and chromium compounds and generated more TCLP toxic ash.<sup>2</sup> In Test 3, three metals exhibited TCLP/ash metal concentration ratios greater than 0.05. This would seem to indicate that a nonrepresentative sample was taken of either the ash that was analyzed for total metals or the ash that was subjected to the TCLP extraction. Nevertheless, even after the

TABLE 6-3. RATIO OF METAL CONCENTRATIONS IN TCLP EXTRACT OF ASH  
TO METAL CONCENTRATIONS IN ASH

Metal	Test Run Number									
	1A	1B	Test 1 Average	2A	2B	Test 2 Average	3B	4A	4B	Test 4 Average
Arsenic	0 <sup>a</sup>	0	0	0	0	0	0.00063	0.0019	0	0.00095
Barium	0.00045	0.00022	0.00034	0.0001	0.0028	0.0014	0.0012	0.0018	0.010	0.0059
Cadmium	0.0042	0.0035	0.0038	0.00077	0.0015	0.0011	1.45	0.008	0.25	0.13
Chromium	0	0.000070	0.000035	0	0	0	0.067	0.00045	0.0015	0.00098
Lead	0.00032	0.0025	0.0014	0.00059	0.00016	0.00038	0.0065	0.0045	0.0028	0.0036
Mercury	ND <sup>b</sup>	ND	ND	ND	ND	ND	0	ND	ND	ND
Selenium	ND	ND	ND	ND	C	0	ND	ND	ND	ND
Silver	0.0040	0.0031	0.0036	0.00029	0.0011	0.00070	0.89	0	ND	0

<sup>a</sup> Metal was detected in the ash but not in the TCLP extract.

<sup>b</sup> Metal was not detected in the ash or the TCLP extract.

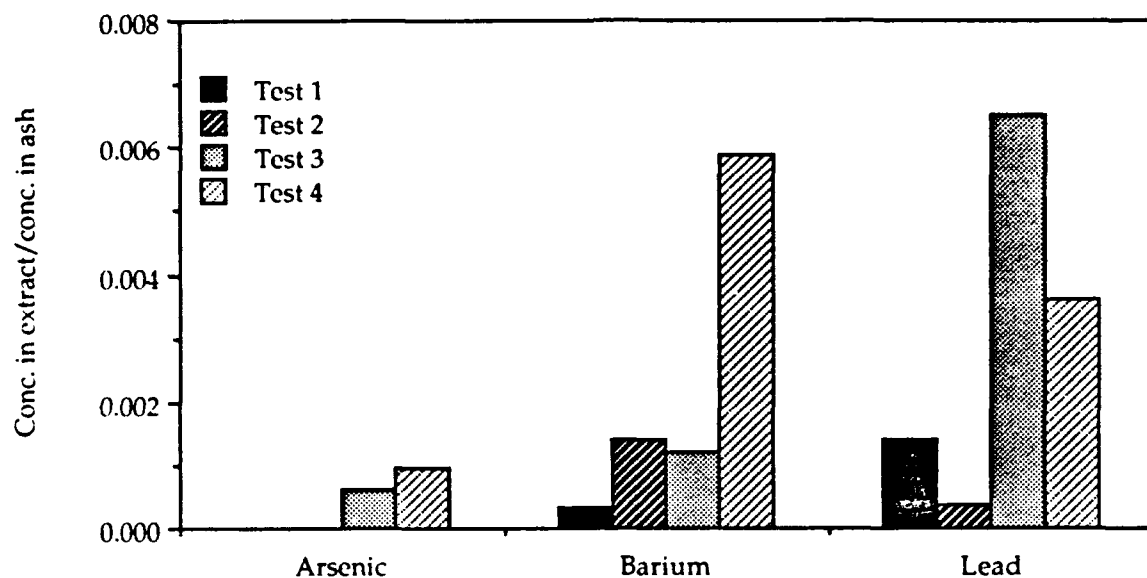


Figure 6-3. Concentration of metals in TCLP extract relative to ash (low ratios).

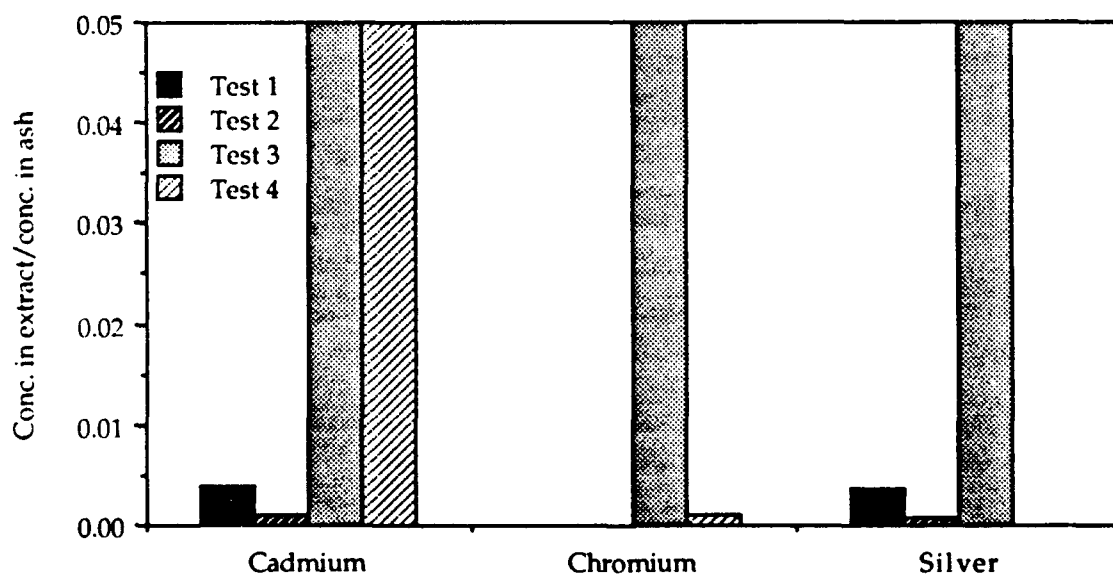


Figure 6-4. Concentration of metals in TCLP extract relative to ash (high ratios).

use of 0.05 as an upper TCLP/ash limit, a comparison of Tests 2 and 4 shows an apparent trend for higher temperatures to produce an ash that is more leachable.

### 6.3 ATMOSPHERIC EMISSIONS

The hazardous waste destruction and removal efficiencies (DRE's) were greater than 99.999 percent under all operating conditions; therefore, the performance standard of 99.99 percent for hazardous waste incinerators was achieved. Chlorobenzene is ranked third for thermal stability incinerability,<sup>5</sup> and has been validated for use by the VOST sample method;<sup>7</sup> 1,2-Dichlorobenzene is ranked in the 7 to 9 range for thermal-stability incinerability.<sup>7</sup> Because the amount of organics contained in the feed was not significant, the use of surrogate spikes, in effect, establishes an upper limit for organic incinerability; i.e., any similar compounds that are not as thermally stable as either of these two compounds would also be effectively destroyed at the operating conditions tested.

Figure 6-5 summarizes the results of uncontrolled particulate loading to the pollution control system. Greater emissions were observed during the tests at lower kiln and secondary combustion chamber temperatures and longer kiln residence times. These findings are consistent with general incinerator operation principles: higher temperatures and shorter residence times result in less particulates in the atmospheric emissions. The particulate data varied more for runs during the lower-temperature tests (1 and 2). Variations of up to 11 lb/h were shown in Test 1 and variations of about 5 lb/h were noted in Test 2. Variations of less than 1 lb/h occurred in Tests 3 and 4.

Figure 6-6 presents a graphical summary of the particle size data; only the two-run average from each test is shown. At the lower kiln temperature, the majority of particles were larger than 15 micrometers in diameter. At the higher kiln temperature, a greater mass percentage of particles was found to be smaller than a given particle size. Therefore, higher kiln and secondary combustion temperatures result in smaller particles, as expected. Figure 6-6 also shows that, at a given temperature, the two residence time lines lie fairly close together. This indicates that residence time did not have a significant effect on particle size distribution.

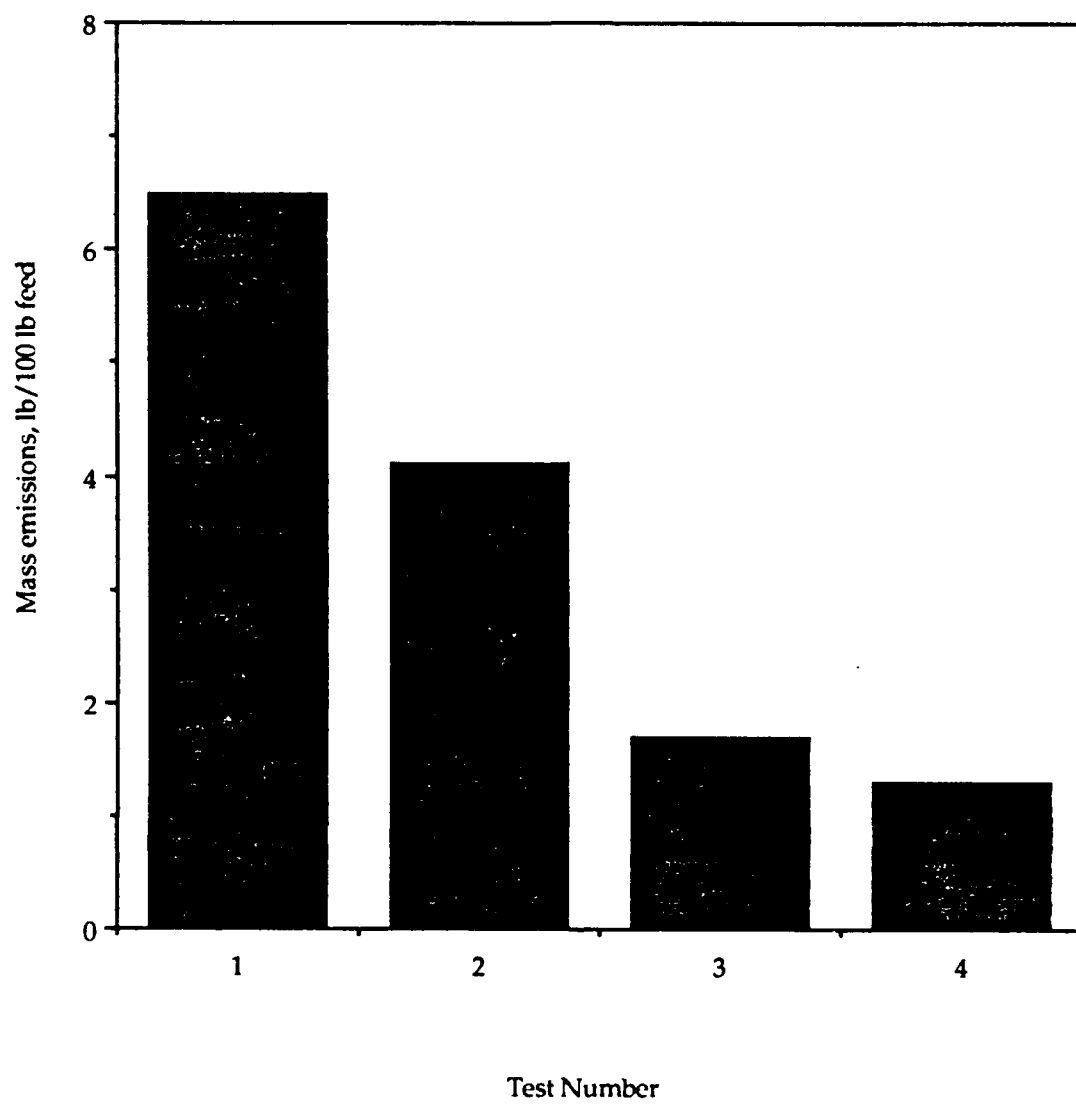


Figure 6-5. Uncontrolled particulate loading.

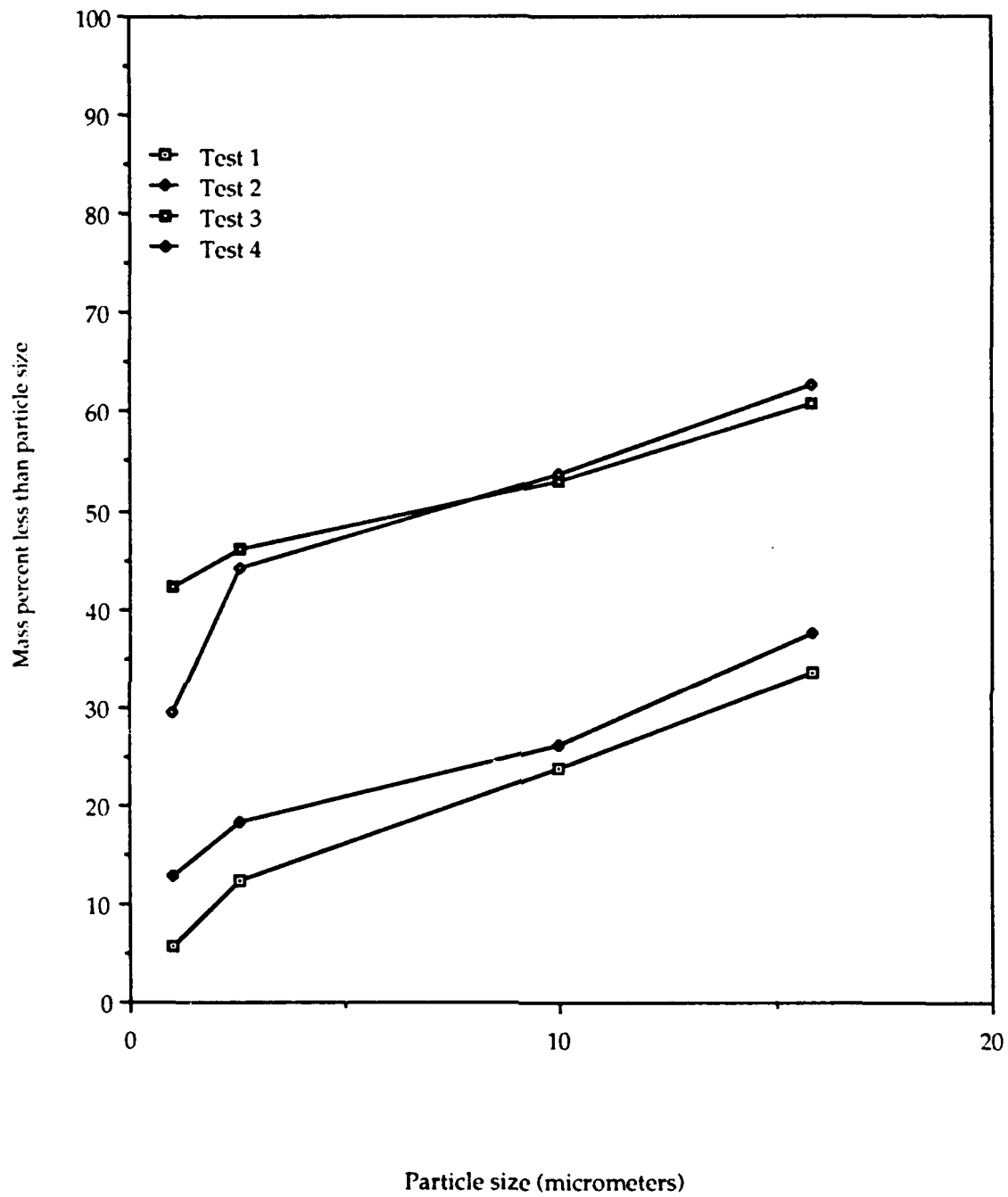


Figure 6-6. Particle size distribution.

Figure 6-7 summarizes the quantity of metals in the feed that were emitted in the flue gas prior to any control devices. This method of evaluating the data normalizes the metals emitted in the stack gas to account for the variations in the feed. Metals that appeared to be emitted at higher rates than were contained in the feed have been assigned a value of 100 percent because a larger value is not possible. Arsenic, cadmium, and lead compounds are more volatile than the other metals; thus, the percentages of these metals in the feed that were emitted in the stack gas are higher. The majority of the metals would be expected to be in particulate form or combined with other particulates generated during incineration (arsenic, cadmium, and mercury are exceptions). The metals data represent filterable plus condensable fractions.

Table 5-17 summarized the data for HCl emissions. The chlorine content in the waste feed was less than 0.11 percent during all tests (<21 lb/h), and the chlorobenzene and 1,2-dichlorobenzene spikes contributed about 10 lb/h of chlorine into the incinerator. Therefore, measured HCl emissions for Runs 1A, 2A, 2B, 3A, and 3B consisted primarily of chlorine resulting from the surrogate spiking compounds. Data from Runs 1B, 4A, and 4B, even after being corrected for chlorine input from the feed, show significant amounts of HCl emissions, ranging from 12 to 29 lb/h. These data are evidently biased high, based on the chlorine input to the incinerator. All laboratory data and sample analysis data sheets were checked to preclude possible cross-contamination or other sources of this bias. None was found, and no current explanation exists for this anomaly.

As expected by the combustion reaction equation, the  $O_2$  and  $CO_2$  data corresponded with each other, so that higher  $O_2$  values coexist with lower  $CO_2$  values. The  $O_2$  and  $CO_2$  data collected by CEM after the secondary combustion chamber should be equal to the data collected by the integrated bag samples after the conditioning tower (on a dry basis). A comparison of Tables 5-12 and 5-19 through 5-26 showed that the  $O_2$  values were higher after the conditioning tower than after the secondary combustion chamber and that the  $CO_2$  values were lower. This indicates that air is entering the system between the two sampling points, increasing the  $O_2$  content, and diluting the  $CO_2$  concentrations. The air could be introduced into the system by leaks in the conditioning tower (the negative pressure in the system would draw air inwards) or through the water pipes.



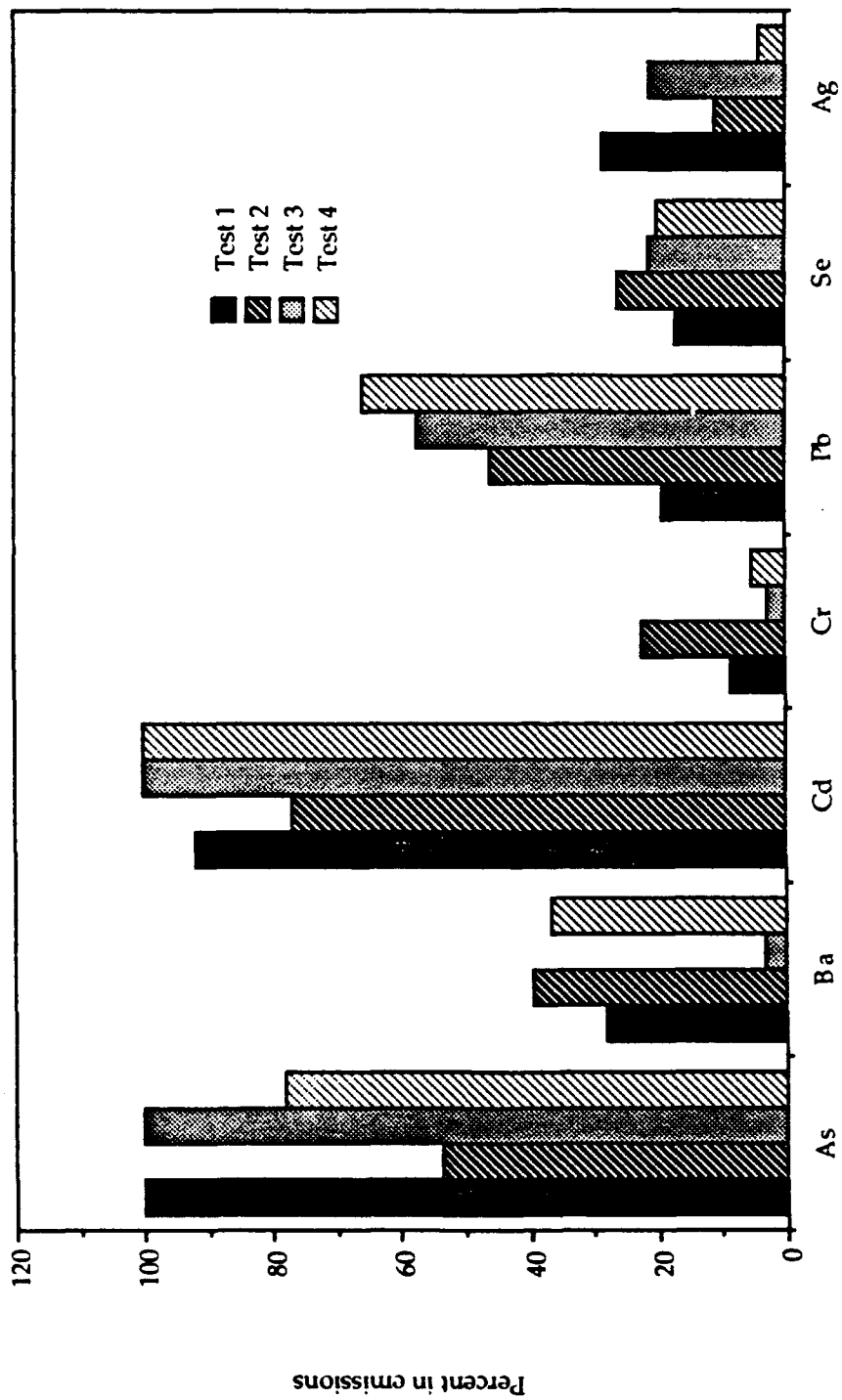


Figure 6-7. Percent of metals in feed emitted in stack gas

## SECTION 7

### CONCLUSIONS AND RECOMMENDATIONS

#### 7.1 CONCLUSIONS

Based on the results presented in Section 5 and the evaluation presented in Section 6 of this report, several conclusions can be drawn regarding incineration of spent plastic and agricultural blast media. The primary conclusion is that spent plastic and agricultural blast media can be readily incinerated by a conventional rotary-kiln incineration system. Destruction and Removal Efficiencies (DRE's) in excess of 99.99 percent were achieved at each operational condition evaluated. This indicates that if other organic-containing paint wastes were mixed with the spent blast media prior to incineration and the incineration was conducted under the same conditions, destruction of the organics would meet the RCRA requirements.

The kiln ash generated during these pilot-scale incineration tests was nonhazardous, with the exception of ash generated during one of the eight runs. Because of the variability in the metals content of the spent blast media generated by depot operations, however, it is not possible to conclude that, in general, ash generated by incineration of this waste would be nonhazardous. The volume of kiln ash generated was less than two percent of the volume of the waste incinerated. It was observed that higher temperatures and longer kiln residence times generated less kiln ash. Such a dramatic reduction in waste volume (>98 percent) would reduce the long-term liabilities associated with landfilling as currently practiced.

Higher uncontrolled particulate emissions occurred at lower temperatures and longer residence times. Lead and zinc were the primary metals present in the stack emissions. Engineering data on the characteristics of the uncontrolled air emissions (i.e., data collected prior to any control device) were collected and will serve as the basis of future evaluations of gas cleaning systems.

## 7.2 RECOMMENDATIONS

Although this study has demonstrated that incineration of two paint wastes--plastic blast media and walnut shells--is feasible, additional work needs to be completed before a full-scale unit can be designed for specific depots. Future projects concerning assessments of the feasibility of incineration in managing paint wastes generated by Army depots should address the following:

- ° Additional tests with other types of paint waste. Fourteen types of paint waste were sampled at the outset of this project. Only two were actually tested; however, these two account for about 50 percent of the waste generated at LEAD. Because many of the other wastes are liquids and sludges that contain various organics, inorganics, and potentially carcinogenic compounds, they will present increasingly more severe disposal problems in the future. Pilot-scale incineration studies should be conducted on these wastes to determine the characteristics of the waste, the ash generated from incineration, and the atmospheric emissions. Data from these studies would be combined with the data from this project to determine incineration conditions including emission controls.
- ° This project focused on atmospheric emissions prior to any control device. Data from this test and other pilot tests should be used to determine applicable emission control devices and to assess the residues generated by such devices.
- ° The material-handling aspects of paint waste incineration need to be evaluated to determine which wastes can be mixed together, the method of mixing and feeding, and where the wastes could be mixed.
- ° A detailed cost evaluation of incineration must be conducted to determine the cost-effectiveness of incineration relative to current practices. As more data are collected on the different wastes and the material handling aspects, the cost evaluations will become more accurate.
- ° If incineration is determined to be the most feasible waste management strategy for paint wastes, the needs of specific Army depots must be evaluated to determine the best method of implementing incineration technology at the depots. This would include determining whether an incinerator should be built at a specific depot or at a central location. It would also be necessary to identify any paint waste that differs significantly from the wastes tested and to determine the incinerability of such wastes.

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APPENDIX  
JOHN ZINK OPERATIONAL DATA

## JOHN ZINK SERVICES, INC.

## Rotary Kiln System Test Data Sheet

Customer: PEI/Army

Shop Order:

Test No. T-1179

Pg. 1 of 3

Date: 8/25/82

by: John

Feed Rate: 195#/hr blast media 25 RPM

1300

Time (24 hr. Clock)	0910	0940	1000	1030	1100	1130	1200	1230	1300
Kiln Burner (%/Press)	27/25	15/25	16/25	16/25	16/25	16/25	16/25	15/25	16/25
Kiln Pressure ("H2O)	.05	.45	.43	.3-.7	.45	.25	.45	.55	.60
Kiln RPM	.25	-	.25	.25	.25	.25	.25	.25	.25
(1) Kiln Temp. (F.)	1416	1510	1435	1397	1606	1614	1589	1653	1545
Kiln % O2 Dry	5.2	7.5	9.2	12	9.0	5.0	8.0	12.5	5.9
Kiln Air D. P. ("H2O)	.5	1.0	1.0	.9	1.5	1.4	1.4	1.4	1.4
ON Kiln Temp °F FRONT/BACK	-	-	-	-	-	-	-	1850/1600	1650/1500
Sec'y. Burner (%/P)	25/25	28/25	28/25	26/25	22/25	22/25	24/25	22/25	24/25
Sec'y. Pressure ("H2O)	-	-	-	-	-	-	-	25	-
(2) Sec'y. Temp. (F.)	1641	1597	1582	1647	1578	1599	1613	1639	1594
Sec'y. % O2 Dry	1.8	6.0	7.0	7.8	6.2	5.0	5.0	4.6	7.0
Sec'y. Air D.P. ("H2O)	1.3	1.6	1.5	1.5	1.7	1.7	1.8	1.8	1.8
Conditioning Tower Water Rota, %	12	18	24	26	20	20	24	22	26
C.T. Water Psg guns E/W	42/42	51/50	46/42	56/56	52/42	52/56	54/56	56/56	52/46
C.T. Air ATMIZ Psg E/W	74/74	82/75	84/80	82/80	80/78	80/78	82/80	84/80	80/60
C.T. Temp.	604	652	647	624	564	622	632	613	576
(3) Quench Inlet T. (F.)	-	-	-	-	-	-	-	250	65
Quench Outlet T. (F.)	145	150	150	150	150	150	150	150	150
Q. Water Flow Rota. %	50	48	48	78	76	76	74	77	76
Water Psg (psig)	-	-	-	-	-	-	-	0	0
Venturi H2O % (L/R)	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60
Venturi H2O P (psig)	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5
Venturi Diff. ("H2O)	36.5	34.3	31.0	29	33	31	31	31	30
(4) Sep. Temp. (F.)	165	165	173	175	168	172	171	172	174
Separator Level (")	24"	40"	40"	37"	41"	40"	42"	38"	38"
Separator M/U %	0-100	90-100	26	0	0	0	0	0-30%	0
Sep. Blowdown (%)	0	0	0	0	0	0	0	0	0
Caustic Flow (%)	0	0	*	*	*	*	*	*	*
Comments	START FEED 0910		2 min 704cc 55%	8 min 50%	5 min 304cc 50%	3 min 304cc 45%	6 min 50%		

## JOHN ZINK SERVICES, INC.

## Rotary Kiln System Test Data Sheet

Customer: PEI/ARMY

Shop Order:

Test No. T-1179Date: 8/29/86

Jy:

Feed Rate:

Pg. 2 of 3

Time (24 hr. Clock)	1330	1400	1430	1500	1530	1600	1630	1700	1730
Kiln Burner (%/Press)	16/25	16/25	16/25	16/25	16/25	15/25	16/25	16/25	16/25
Kiln Pressure ("H2O)	.55	.5-.7	.8-1.0	.4-.7	.40	.75	.55	.55	.55
Kiln RPM	.25	.25	.25	.25	.25	.25	.25	.25	.25
(1) Kiln Temp. (F.)	1507	1550	1569	1550	1512	1685	1593	1645	1594
Kiln % O2 Dry	15.0	15.0	10.0	8.2	10	14.0	6.0	8.5	4.0
Kiln Air D. P. ("H2O)	1.5	1.5	1.2	1.1	1.1	1.1	1.1	1.1	1.1
ON KILN T OF FRONT/BACK	1600/1400	1600/1500	1650/1500	1650/1500		1740/1600	1700/1500	1750/1500	1700/1500
Sec'y. Burner (%/P)	24/25	24/25	24/25	24/25	14/25	17/25	20/25	20/25	20/25
Sec'y. Pressure ("H2O)	-	-	-	-	-	-	-	-	-
(2) Sec'y. Temp. (F.)	1587	1639	1606	1655	1745	1568	1589	1581	1576
Sec'y. % O2 Dry	6.0	5.0	6.0	3.0	2.5	7.9	7.0	9.0	7.5
Sec'y. Air D.P. ("H2O)	1.7	1.8	1.8	1.8	1.8	2.1	1.9	1.6	1.6
Conditioning Tower <sup>water</sup> Rota. %	22	22	26	24	30	30	26	28	24
C.T. Water Big guns E/W	54/54	54/54	58/60	54/54	58/60	60/60	58/58	58/58	54/
C.T. AIR ATOMIZE Psig E/W	80/80	82/80	84/80	82/80	84/80	82/82	80/80	80/80	80/
2 C.T. Temp °F	592	649	648	586	601	549	647	574	603
(3) Quench In. T. (F.)	70/30	70/30	70/30	70/30	69/28	60/0	80/40	85/32	80/40
Quench Outlet T. (F.)	150	150	150	150	150	150	150	150	150
Q. Water Flow Rota. %	72	74	74	70	72	70	70	70	60
Water Press. (psig)	0	0	0	0	0	0	0	0	0
Venturi H2O % (L/R)	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60
Venturi H2O P (psig)	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5
Venturi Diff. ("H2O)	29.5	28	28	30.5	27.5	22.0	24.0	27.5	27.5
3 (3) Sep. Temp. (F.)	174	176	175	175	178	167	173	172	170
Separator Level (%)	A0	A0	39	41	41	41	35	35	35
Separator M/U %	30%	30	30	30	0	0	50	72	72
Sep. Blowdown (%)	0	0	84	82	78	100	100+	100+	100+
Caustic Flow (%)	*	*	*	*	*	*	*	*	*
Comments						12 min 70% 162 ft 8 1/2 min		1727 7 1/2 min	PH-7 6 min 60%

## JOHN ZINK SERVICES, INC.

## Rotary Kiln System Test Data Sheet

Customer: *Pei/Army*

Shop Order:

Test No. *T-1179*Date: *8-25-8**Pg. 3 of*

by:

Feed Rate:

1 hr.

Time (24 hr. Clock)	1800	1830							
Kiln Burner (%/Press)	16/25	15/25							
Kiln Pressure ("H2O)	.45	.65							
Kiln RPM	.25	.25							
(1) Kiln Temp. (F.)	1650	1630							
Kiln % O2 Dry	5.7	8.0							
Kiln Air D. P. ("H2O)	1.2	1.3							
on kiln T/F Front/Back	1750/1550	1750/1550							
Sec'y. Burner (%/P)	22/25	21/25							
Sec'y. Pressure ("H2O)	—								
(2) Sec'y. Temp. (F.)	1601	1620							
Sec'y. % O2 Dry	8.5	8.5							
Sec'y. Air D.P. ("H2O)	2.0	1.2							
Conditioning Tower <sup>water</sup> Rota. %	26	25							
C.T. Water Big guns E/W	46/58	54/54							
C.T. AIR Atomizer Psig E/W	82/80	80/80							
2 C.T. Temp. F	537	538							
(3) Quench In. T. (F.)	80/35	80/35							
Quench Outlet T. (F.)	150	135							
Q. Water Flow Rota. %	60	57							
Water Press. (psig)	17	0							
Venturi H2O % (L/R)	60/60	60/60							
Venturi H2O P (psig)	10/5	10/5							
Venturi Diff. ("H2O)	25	39							
3 (5) Sep. Temp. (F.)	170	168							
Separator Level (%)	34	38							
Separator M/U %	58	80							
Sep. Blowdown (%)	100+	100+							
Caustic Flow (%)	1*								
Comments		1830 Shut off water							



## JOHN ZINK SERVICES, INC.

## Rotary Kiln System Test Data Sheet

Customer: PEI/ARMY

Shop Order:

Test No. T-1179

Pg. 1 of 2

Date: 8-26-81

Jy:

Feed Rate: 195#/hr Pry 30min

Time (24 hr. Clock)	0700	0730	0800	0830	0900	0930	1000	1030	1100
Kiln Burner (%/Press)	15/25	15/25	15/25	15/25	26/25	15/25	36/25	19/25	15/25
Kiln Pressure ("H2O)	.3	.6	.6	.3-5	.80	.60	.50	.30	.60
Kiln RPM	.5	.5	.5	.5	.5	.5	.5	.5	.5
(1) Kiln Temp. (F.)	1480	1459	1505	1482	1490	1512	1480	1498	1492
Kiln % O2 Dry	6.0	7.5	8.3	5.0	5.0	5.5	-X	-X	10.0
Kiln Air D. P. ("H2O)	2.0	2.1	2.1	2.0	2.0	2.0	2.0	2.0	2.0
ON KILN OF FRONT/BACK	1725/1425	1450/1400	1725/1440	1650/1450	1750/1500	1700/1500	1700/1450	1700/1450	1700/1450
Sec'y. Burner (%/P)	24/25	24/25	22/25	23/25	23/25	21/25	21/25	21/25	22/25
Sec'y. Pressure ("H2O)	-	-	-	-	-	-	-	-	-
(2) Sec'y. Temp. (F.)	1611	1618	1615	1616	1620	1623	1611	1606	1608
Sec'y. % O2 Dry	9.0	6.3	7.8	7.0	5.0	5.0	6.0	7.5	6.5
Sec'y. Air D.P. ("H2O)	.7	.7	.7	.7	.6	.6	.7	.7	.7
Conditioning Tower <sup>water</sup> Rota. %	20	23	23	19	23	26	18	22	22
C.T. Water Psg guns E/W	50/50	54/54	54/54	52/50	54/54	56/54	40/50	52/52	54/54
C.T. AIR HUMID. Psg E/W	90/80	90/80	92/80	88/74	80/40	80/40	88/78	88/80	90/80
Kiln Quench Gun <sup>H2O</sup> STm	0/0	30/75	0/0	0/0	18/50	20/50	0/0	10/25	10/30
(3) Quench Inlet T. (F.)	683	635	621	672	612	621	638	616	605
COND. TOWER OUT									
Quench Outlet T. (F.)	146	150	148	148	148	150	145	150	150
Q. Water Flow Rota. %	18	53	50	50	48	46	44	45	44
Water Press. (psig)	0	~1-29	0	0	0	0	0	0	0
QUENCH KILN Rota. %	60	60	60	60	60	60	60	60	60
Venturi H2O % (L/R)	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60
Venturi H2O P (psig)	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5
Venturi Diff. ("H2O)	32	22.5	24	24.5	26.0	22	28	24.5	24.5
(5) Sep. Temp. (F.)	165	173	174	172	170	175	173	172	174
Separator Level (%)	33	34	33	32	34	42	34	32	32
Separator M/U %	0	30	30	73	48	50	0	0	0
Sep. Blowdown (%)	100	95+100	100+	100+	100+	100+	100+	100+	100+
Caustic Flow (%)	*	* ↓	*	*	*	*	*	*	*
Comments	START FEED 00643 100% 1.5min	100% 1min	100% 2.5min	80% 4min 30 min	4:08 last fine incinerator 2-min	100% 2min	10:00 STOP FEEDING 2 1/2 min 0% 6%	10:23 Start Feeding For 2nd sample run	10:40 mid 100% 5 min
			A-5				* Kiln meter out		

## JOHN ZINK SERVICES, INC.

## Rotary Kiln System Test Data Sheet

Customer: PEE/ARMY

Shop Order:

Test No. T-1177

Date: 8/26/88

JY:

Feed Rate: 195# DCY/hr 30 MIN RES. TIME

Time (24 hr. Clock)	1130	1200	1230	1300	1330				
Kiln Burner (%/Press)	16/15	14/15	14/25	14/25	14/25				
Kiln Pressure ("H2O)	.30	.60	.50	.7	.25				
Kiln RPM	.50	.50	.5	.5	.5				
(1) Kiln Temp. (F.)	1499	1494	1553	1510	1494				
Kiln % O2 Dry	9.5	6.0	5.8	9.0	7.0				
Kiln Air D. P. ("H2O)	2.0	2.0	2.0	2.0	2.0				
on kind of Front/Back		1700/145	1675/145	1710/1490	1700/145				
Sec'y. Burner (%/P)	21/25	21/25	20/25	20/25	21/25				
<del>Sec'y. Recs Recr ("H2O)</del>	-	-	-	-	-				
(2) Sec'y. Temp. (F.)	1612	1606	1625	1615	1616				
Sec'y. % O2 Dry	4.5	4.5	6.0	6.8	6.0				
Sec'y. Air D.P. ("H2O)	.6	.6	.65	.65	.60				
Conditioning Tower <sup>water</sup> Rota. %	22	26	24	23	25				
C.T. Water Big guns E/W	54/56	58/48	54/58	54/54	52/52				
C.T. AIR ATOMIZ. Psig E/W	80/80	90/80	90/80	84/80	76/80				
Kiln Quenchair <sup>STN</sup> /H2O	70/40	80/40	100/45	40/15	45/20				
<del>Quench Inlet T. (F.)</del>	608	626	606	637	617				
Quench Outlet T. (F.)	150	150	150	150	150				
Q. Water Flow Rota. %	40	36	38	36	32				
<del>Water Flow Rota. (psig)</del>	0	0	410	410	410				
Venturi H2O % (L/R)	60/60	60/60	60/60	60/60	60/60				
Venturi H2O P (psig)	10/5	10/5	10/5	10/5	10/5				
Venturi Diff. ("H2O)	23	21	23	23	22.5				
SEA Sep. Temp. (F.)	176	175	175	176	176				
Separator Level (%)	32	32	34	34	34				
Separator M/U %	38	38	36	34	35				
Sep. Blowdown (%)	100+	100+	82-100+	100+	100+				
Caustic Flow (%)	*	*	*	*	*				
Comments	60% 5 min	60% 4 min	60% 4 min	50% 5 min	34 min 60%				
A-6									
1340 STOP FEED FINISHED									

AIR at 148

## JOHN ZINK SERVICES, INC.

Rotary Kiln System Test Data Sheet

Customer: PEI/ARMY

Shop Order:

Test No.

Date: 8-27-88

by: John

Feed Rate: 195<sup>kg</sup> DRY/Hr. 1hr.

START SAMPLING - 0725

Time (24 hr. Clock)	0630	0700	0730	0800	0830	0900	0930	1000	1030
Kiln Burner (%/Press)	34/25	24/25	14/25	14/25	14/25	14/25	14/25	15/25	15/25
Kiln Pressure ("H2O)	.30	.30	.10	.20	.15	0	.45	.35	.30
Kiln RPM	.25	.25	.25	.25	.25	.25	.25	.25	.25
(1) Kiln Temp. (F.)	1789	1798	1804	1844	1798	1798	1807	1797	1795
Kiln % O2 Dry	5.3	3.4	5.0	5.5	5.5	4.0	7.0	9.0	7.0
Kiln Air D. P. ("H2O)	2.7	2.1	1.9	1.9	2.4	2.1	2.9	3.5	3.5
Kiln P. meters °F FRONT/BACK	2050/1800	2100/1800	2100/1800	2100/1900	2050/1800	2050/1800	2050/1800	2050/1750	2050/1800
Sec'y. Burner (%/P)	47/25	42/25	42/25	42/25	44/25	34/25	28/25	32/25	34/25
(2) Sec'y. Temp. (F.)	1982	1998	1980	2006	2009	2013	1961	1977	1998
Sec'y. % O2 Dry	6.0	7.0	3.0	3.7	7.0	7.0	7.0	6.5	4.5
Sec'y. Air D.P. ("H2O)	1.5	1.3		2.2	2.2	.60	.60	.60	.60
Conditioning Tower Water Rota. %	36	38	36	36	38	32	32	36	36
C.T. Water Pigs guns E/W	64/64	64/64	64/64	64/64	64/64	62/62	62/62	64/64	62/64
C.T. Air Atomiz. Pigs E/W	85/85	84/85	84/85	84/84	82/82	84/84	84/84	84/84	84/82
C.T. °F OUT	659	601	601	606	593	549	675	635	605
Quench Outlet T. (F.)	150	150	150	150	150	150	150	150	150
Q. Water Flow Rota. %	49	46	42	42	50	42	46	42	52
Venturi H2O % (L/R)	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60
Venturi H2O P (psig)	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5
Venturi Diff. ("H2O)	20	20	21	20	20	26.5	22	22	23
(5) Sep. Temp. (F.)	176	177	174	174	175	175	176	174	174
Separator Level (%)	~42	34	34	34	34	33	34	0	31
Separator M/U %	0	40	40	40	40	40	40	40	40
Sep. Blowdown (%)	100+	100+	100+	100+	100+	100+	100+	100+	100+
Caustic Flow (%)	*	*	*	*	*	*	*	*	*
Comments	1 min 100%	1 min 100%	1 1/2 min 100%	3 min 100%	5 min 50%	3 min 50%	6 min 50%	changed drill trip	10:05 5 min 50%

Stopper Sample  
run @ 10:30

A-7

96100001 REVISE - 3.24.1

10000000 -

AIR 71m  
100°

JOHN ZINK SERVICES, INC.

Rotary Kiln System Test Data Sheet

Customer: PEI CUMY

Shop Order:

Test No. T-1179

Date: 8.27.88

By:

Feed Rate: 195 # D.7/16

Time (24 hr. Clock)	1100	1130	1200	1230	1300	1330	1400	1430	1500
Kiln Burner (%/Press)	16/25	16/25	18/25	16/25	21/25	20/25	20/25	20/25	19/25
Kiln Pressure ("H2O)	0	.20	.20	.45	.20	.40	.70	.60	.52
Kiln RPM	.25	.25	.25	.25	.25	.25	.25	.25	.25
(1) Kiln Temp. (F.)	1816	1820	1830	1811	1802	1787	1779	1771	1785
Kiln % O2 Dry	6.5	5.5	6.0	4.5	?	9.0	7.5	7.5	7.3
Kiln Air D. P. ("H2O)	3.5	3.4	4.7	4.6	4.6	4.7	4.8	4.6	4.7
Kiln Pyrometers °F FRNT/BACK	2000/1750	2000/1750	2000/1750	2000/1725	2050/1750	2000/1750	2000/1750	2050/1750	2050/1750
Sec'y. Burner (%/P)	32/25	32/25	32/25	31/25	31/25	30/25	30/25	30/25	30/25
(2) Sec'y. Temp. (F.)	2007	2013	2018	2019	2011	1996	1983	1982	1987
Sec'y. % O2 Dry	8.0	6.0	7.5	6.8	7.0	6.5	6.5	6.0	8.0
Sec'y. Air D.P. ("H2O)	.6	.5	.6	.6	.5	.5	.5	.6	.7
Conditioning Tower Wt% Rota, %	35	38	37	36	36	38	36	38	40
C.T. Water Pigs E/W	64/64	64/64	64/64	64/64	64/64	64/64	64/64	64/64	64/64
C.T. Air 20m/z Pigs E/W	84/84	84/84	84/84	84/84	84/84	84/84	84/84	84/84	84/84
2 C.T. °F OUT	600	575	648	606	595	623	588	621	588
Quench Outlet T. (F.)	150	150	150	150	150	150	150	150	150
Q. Water Flow Rota. %	40	40	72	96	100	98	96	96	90
Venturi H2O % (L/R)	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60
Venturi H2O P (psig)	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5
Venturi Diff. ("H2O)	23	24	20.5	18	19.5	17	22	16	16
(5) Sep. Temp. (F.)	175	175	175	175	175	177	175	176	175
Separator Level (%)	30	47	47	47	47	47	47	47	47
Separator M/U %	0	0	0	0	0	0	0	0	0
Sep. Blowdown (%)	100	22	22	0	0	16	16	14	0
Caustic Flow (%)	*	*	*	*	*	*	*	*	*
Comments	5 min 50%	5 min 50% 5 min 100% C/11/5			6 min 100%	3 min 100% water	6 min 100% water 3 min 100% water	6 min 100% water	

A-8

Shift  
Down  
150

## JOHN ZINK SERVICES, INC.

## Rotary Kiln System Test Data Sheet

Customer: P13 A

Shop Order:

Test No. 7

Date: 8-28-88

y:

Feed Rate:

Time (24 hr. Clock)	0700	0800	0900	1000	1100	1200	1300	1400	1500
Kiln Burner (%/Press)	20/25	15/25	14/25	16/25	17/25	14/25	14/25	15/25	50/25
Kiln Pressure ("H2O)	.20	.40	.30	.25	.30	.40	.1	.20	.20
Kiln RPM	.25	.25	.25	.30	.25	.25	.25	.25	.25
(1) Kiln Temp. (F.)	1753	1786	1851	1748	1749	1832	1783	1801	1767
Kiln % O2 Dry	5.5	9.0	5.5	8.0	5.5	6.5	6.0	8.0	6.0
Kiln Air D. P. ("H2O)	2.4	2.4	2.3	2.7	1.9	3.0	2.5	2.5	2.5
Kiln Pyrometers °F Front/Back	2125/1850	2100/1850	2125/1900	2100/1750	2100/1875	2100/1875	2100/1875	2100/1875	2100/1875
Sec'y. Burner (%/P)	40/25	40/25	40/25	42/25	40/25	40/25	40/25	38/25	40/25
2) Sec'y. Temp. (F.)	1992	1975	1961	1988	1947	1996	1993	2003	2008
Sec'y. % O2 Dry	3.5	5.5	3.5	5.0	4.0	4.0	5.5	5.7	5.5
Sec'y. Air D.P. ("H2O)	2.1	2.1	2.1	2.1	2.1	2.0	2.1	2.1	2.1
Conditioning Tower Rota. %	36	34	36	40	36	38	44	38	42
C.T. Water Pigs E/W	62/62	64/62	64/62	64/62	64/62	64/62	64/62	64/62	64/62
C.T. Air Admix Pigs E/W	62/62	62/62	62/62	62/62	62/62	64/64	70/64	90/64	87/64
C.T. °F OUT	647	641	613	599	580	625	593	596	622
Quench Outlet T. (F.)	150	150	150	150	150	150	150	150	150
Water Flow Rota. %	70	74	74	72	77	70	100	100	100
Venturi H2O % (L/R)	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60
Venturi H2O P (psig)	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5
Venturi Diff. ("H2O)	25	19	19	19	13	17	19	19	16
(3) Sep. Temp. (F.)	172	175	173	175	173	176	176	175	174
Separator Level (%)	50	49	47	50	50	50	45	50	50
Separator M/U %	0	0	0	0	0	0	0	0	0
Sep. Blowdown (%)	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Clustic Flow (%)	*	*	*	*	*	*	*	*	*
Comments	110 FEED								1115 FEED

## JOHN ZINK SERVICES, INC.

## Rotary Kiln System Test Data Sheet

Customer: 932/1444

Shop Order:

Test No.:

Date: :

by:

Feed Rate:

Time (24 hr. Clock)	1130	1200	1230	1300	1330	1400	1430	1500	1530
Kiln Burner (%/Press)	76/25	16/25	14/25	14/25	18/25	22/25	28/25	32/25	14/25
Kiln Pressure ("H2O)	.3	.5	.4	.10	.20	.45	.40	.30	.25
Kiln RPM	.25	.25	.25	.25	.25	.25	.25	.25	.25
(1) Kiln Temp. (F.)	1816	1801	1825	1816	1795	1796	1860	1823	1830
Kiln % O2 Dry	7.0	6.0	7.3	7.5	9.0	11.0	9.2	7.4	6.8
Kiln Air D. P. ("H2O)	2.4	2.5	2.2	2.4	3.3	3.5	2.8	2.8	2.8
Kiln Pyrometers °F FRNT/BACK	200/1800	200/1800	200/1800	200/1800	200/1800	200/1800	200/1800	200/1800	200/1800
Sec'y. Burner (%/P)	40/25	38/25	38/25	40/25	40/25	38/25	38/25	38/25	38/25
(2) Sec'y. Temp. (F.)	2003	1997	2005	2009	2003	1994	1999	2007	2011
Sec'y. % O2 Dry	5.5	6.0	5.3	5.0	6.0	7.2	6.0	4.8	4.3
Sec'y. Air D.P. ("H2O)	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1	2.1
Conditioning Tower <sup>water</sup> Rota, %	36	36	36	36	60	39	42	40	40
C.T. Water Psg guns E/W	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60
C.T. Air Psg guns E/W	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60
C.T. °F OUT	571	621	626	580	1-10	631	620	590	588
Quench Outlet T. (F.)	150	150	150	150	150	150	150	150	150
Q. Water Flow Rota. %	100	100	100	100	100	100	100	100	100
Venturi H2O % (L/R)	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60	60/60
Venturi H2O P (psig)	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5	10/5
Venturi Diff. ("H2O)	17	16	16	16.5	16	16	16	25	25
(5) Sep. Temp. (F.)	173	175	175	176	175	175	175	175	175
Separator Level (")	51	46	53	51	50	52	53	53	53
Separator M/U %	0	0	0	0	0	0	0	0	0
Sep. Blowdown (%)	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Caustic Flow (%)	2	2	2	2	2	2	2	2	2
Comments	6 min 100%			5 min 100%					stop 15 min